2 Spurdog in the Northeast Atlantic

2.1 Stock distribution

Spurdog or the piked dogfish, *Squalus acanthias* has a worldwide distribution in temperate and boreal waters, and occurs mainly in depths of 10–200 m. In the NE Atlantic, this species is found from Iceland and the Barents Sea southwards to the coast of Northwest Africa (McEachran and Branstetter, 1984).

WGEF considers that there is a single NE Atlantic stock ranging from the Barents Sea (Subarea 1) to the Bay of Biscay (Subarea 8), and that this is the most appropriate unit for assessment and management within ICES. Spurdog in Subarea 9 may be part of the NE Atlantic stock, but catches from this area are likely to consist of a mixture of *Squalus* species, with increasing numbers of *Squalus blainville* further south.

Genetic microsatellite analyses conducted by Verissimo *et al.* (2010) found no differences between east and west Atlantic spurdog. The authors suggested this could be accomplished by transatlantic migrations of a very limited number of individuals. Further information on the stock structure and migratory pattern of Northeast Atlantic spurdog can be found in the Stock Annex. Nonetheless, recent studies undertaken by Thorburn *et al*. (2018) suggest subpopulations across the UK.

2.2 The fishery

2.2.1 History of the fishery

Spurdog has a long history of exploitation in the Northeast Atlantic (Pawson *et al.*, 2009) and WGEF estimates of total landings are shown in Figure 2.1 and Table 2.1. Spurdog has historically been exploited by France, Ireland, Norway and the UK (Table 2.2). The main fishing grounds for the NE Atlantic stock of spurdog are the North Sea (Subarea 4), West of Scotland (Division 6.a) and the Celtic Seas (Subarea 7) and, during the decade spanning the late 1980s to 1990s, the Norwegian Sea (Subarea 2) (Table 2.3). Outside these areas, landings have generally been low. In recent years the fishery has changed significantly in line with restrictive management measures, which have included more restrictive quota, a maximum landing length and bycatch regulations.

Further details of the historical development of the fishery are provided in the Stock Annex. Further general information on the mixed fisheries exploiting this stock and changes in effort can be found in ICES (2009a, b) and STECF (2009).

2.2.2 The fishery in 2020

The zero TAC for spurdog for EU vessels, introduced in 2011, has resulted in a major change in the magnitude and spatial distribution of reported landings. Between 2005 and 2017, landings declined across all ICES subareas, slightly increasing in 2018, 2019 and 2020.

Since 2011 the annual Norwegian landings, which land significantly more spurdog than other countries, have been fluctuating between 217–370 tonnes. However, reported landings of spurdog from Norwegian fisheries were 409 tonnes in 2020.

In July 2016, an in-year amendment to EU quota regulations saw the introduction of a small TAC (270 t) for Union and international waters of subareas 1, 5–8, 10 and 12 (see Section 2.2.4). During

2018, 2019 and 2020, UK reported landings of 37, 52 and 79 tonnes spurdog, respectively. For UK, traditionally one of the major exploiters of the spurdog stock (prior to 2009), this was a major increase from a level close to zero that has been seen since the zero TAC was introduced in 2011. For other countries which landed spurdog, see Table 2.2.

Commercial fishermen in various areas, including the southern North Sea, the Celtic Sea, and in the south- and mid-Norwegian coastal areas, continue to report that spurdog can be seasonally abundant on their fishing grounds.

2.2.3 ICES advice applicable

In 2020, ICES advised that "*when the precautionary approach is applied, there should be no targeted fisheries on this stock in 2021 and 2022. Based on medium-term projections, annual catches at the recent assumed level (2468 tonnes) would allow the stock to increase at a rate close to that estimated with zero catches. Any possible provision for the landing of bycatch should be part of a management plan, including close monitoring of the stock and fisheries*".

2.2.4 Management applicable

The following table summarises ICES advice and actual management applicable for NE Atlantic spurdog during 2001–2020.

Year	Single-stock exploitation boundary (tonnes)	Basis	TAC (IIa(EC) and IV) (tonnes)	TAC IIIa , I, V, VI, VII, VIII, XII and XIV (EU and international waters) (tonnes)	TAC IIIa(EC) (tonnes)	TAC I, V, VI, VII, VIII, XII and XIV (EU and international waters) (tonnes)	WG landings (NE Atlantic stock) (tonnes)
2000	No advice	-	9470				15 890
2001	No advice	-	8870	-	-	-	16 693 (1)
2002	No advice	-	7100	-	-	-	11 020
2003	No advice	-	5640	-	-	-	12 246
2004	No advice	-	4472	-	-	-	9365
2005	No advice	-	1136	-	-	-	7100
2006	F=0	Stock depleted and in danger of collapse	1051	-	-	-	4015
2007	F=0	Stock depleted and in danger of collapse	841 (2)	2828	-	-	2917
2008	No new advice	No new advice	631 (2,3)	-	-	2004 (2)	1798
2009	F=0	Stock depleted and in danger of collapse	316 (3,4)	-	104 (4)	1002 (4)	1980
2010	F=0	Stock depleted and in danger of collapse	0 (5)		0 (5)	0 (5)	892
2011	F=0	Stock depleted and in danger of collapse	0 (6)		0	0 (6)	435

Year	Single-stock exploitation boundary (tonnes)	Basis	TAC (IIa(EC) and IV) (tonnes)	TAC IIIa , I, V, VI, VII, VIII, XII and XIV (EU and international waters) (tonnes)	TAC IIIa(EC) (tonnes)	TAC I, V, VI, VII, VIII, XII and XIV (EU and international waters) (tonnes)	WG landings (NE Atlantic stock) (tonnes)
2012	F=0	Stock below possible reference points	0 [(6)]		0	0 [(6)]	453
2013	F=0	Stock below possible reference points	0		0	0	335
2014	F=0	Stock below possible reference points	0		0	0	383
2015	F=0	Stock below possible reference points	0		0	0	263
2016	F=0	Stock below possible reference points	0		0	0 (270[(7)])	373
2017	F-0	Stock below possible reference points	0		0	270[(7)]	296
2018	F-0	Stock below possible reference points	0		0	270[(7)]	363
2019	F=0	Stock below possible reference points	0		0	270[(7)]	455
2020	F=0	Stock below possible reference points	0		0	270[(7)]	526

(1) The WG estimate of landings in 2001 may include some misreported deep-sea sharks or other species. (2) Bycatch quota. These species shall not comprise more than 5% by live weight of the catch retained on board. (3) For Norway: including catches taken with longlines of tope shark (*G. galeus*), kitefin shark (*D. licha*), bird beak dogfish (*D. calcea*), leafscale gulper shark (*C. squamosus*), greater lantern shark (*E. princeps*), smooth lanternshark (*E. spinax*) and Portuguese dogfish (*C. coelolepis*). This quota may only be taken in zones IV, VI and VII. (4) A maximum landing size of 100 cm (total length) shall be respected. (5)Bycatches are permitted up to 10% of the 2009 quotas established in Annex Ia to Regulation (EC) No. 43/2009 under the following conditions: catches taken with longlines of tope shark (*G. galeus*), kitefin shark (*D. licha*), bird beak dogfish (*D. calceus*), leafscale gulper shark (*C. squamosus*), greater lantern shark (*E. princeps*), smooth lantern shark (*E. pusillus*) and Portuguese dogfish (*C. coelolepis*) and spurdog (*S. acanthias*) are included (Does not apply to IIIa); a maximum landing size of 100 cm (total length) is respected; the bycatches comprise less than 10% of the total weight of marine organisms on board the fishing vessel. Catches not complying with these conditions or exceeding these quantities shall be promptly released to the extent practicable. (6) Catches taken with longlines of tope shark (*G. galeus*), kitefin shark (*D. licha*), bird beak dogfish (*D. calcea*), leafscale gulper shark (*C. squamosus*), greater lanternshark (*E. princeps*), smooth lanternshark (*E. pusillus*), Portuguese dogfish (*C. coelolepis*) and spurdog (*S acanthias*) are included. Catches of these species shall be promptly released unharmed to the extent practicable. (7) Spurdog shall not be targeted in the areas covered by this TAC. When accidentally caught in fisheries where spurdog is not subject to the landing obligation, specimens shall not be harmed and shall be released immediately, as required by Articles 12 (13 in 20180 and 41 (45 in 2018) of this Regulation. By derogation from Article 12 of this Regulation, a vessel engaged in the by-catch avoidance programme that has been positively assessed by the STECF may land not more than 2 tonnes per month of spurdog that is dead at the moment when the fishing gear is hauled on board. Member States participating in the by-catch avoidance programme shall ensure that the total annual landings of spurdog on the basis of this derogation do not exceed the above amounts. They shall communicate the list of participating vessels to the Commission before allowing any landings. Member States shall exchange information about avoidance areas.

In all EU regulated areas, a zero TAC for spurdog was retained for 2019. In July 2016, an in-year amendment to EU quota regulations (Council Regulation (EU) 2016/1252 of 28 July 2016) saw the introduction of a small TAC (270 t) for Union and international waters of subareas 1, 5–8, 10 and 12, with this TAC to be allocated to vessels participating in bycatch avoidance programmes. This regulation states that "*a vessel engaged in the by-catch avoidance programme that has been positively assessed by the STECF may land not more than 2 tonnes per month of picked dogfish that is dead at the moment when the fishing gear is hauled on board. Member States participating in the by-catch avoidance programme shall ensure that the total annual landings of picked dogfish on the basis of this derogation do not exceed the amounts indicated below. They shall communicate the list of participating vessels to the Commission before allowing any landings. Member States shall exchange information about avoidance areas*".

This derogation was not denoted for TAC areas for EU waters of 3.a or EU waters of 2.a and 4. In these areas, no EU landings were permitted.

In 2007, Norway introduced a general ban on target fisheries for spurdog in the Norwegian economic zone and in international waters of ICES subareas 1–14, with the exception of a limited fishery for small coastal vessels. Bycatch could be landed and sold as before. All directed fisheries were banned from 2011, although there is still a bycatch allowance. From October 2011, bycatch should not exceed 20% of total landings on a weekly basis. Since 4 June 2012, bycatch must not exceed 20% of total landings over the period 4 June–31 December 2012. From 1 January 2013, bycatch must not exceed 15% of total landings on a half calendar year basis. Live specimens can be released, whereas dead specimens must be landed. From 2011, the regulations also include recreational fisheries. Norway has a 70 cm minimum landing size (first introduced in 1964).

Since 1 January 2008, fishing for spurdog with nets and longlines in Swedish waters has been forbidden. In trawl fisheries, there is a minimum mesh size of 120 mm and the species may only be taken as a bycatch. In fisheries with hand-held gear only one spurdog was allowed to be caught and kept by the fisher during a 24-hour period.

Many of the mixed fisheries which caught spurdog in the North Sea, West of Scotland and Irish Sea are subject to effort restrictions under the cod long-term plan (EC 1342/2008).

2.3 Catch data

2.3.1 Landings

Total annual landings of NE Atlantic spurdog are given in Table 2.1 and illustrated in Figure 2.1. Preliminary estimates of landings for 2020 were 526 t.

2.3.2 Discards

Estimates of total amount of spurdog discarded are not routinely provided although some discard sampling does take place in several countries.

Data from Scottish observer trips in 2010 were made available to the WG. Over 1200 spurdog (raised to trip level and then summed across trips) were caught over 29 trips (across divisions 4.a and 6.a), but on no occasion were any retained.

At the 2010 WG, a working document was presented on the composition of Norwegian elasmobranch catches, which suggested significant numbers of spurdog were discarded.

Preliminary observations on the discard-retention patterns of spurdog as observed on UK (English) vessels were presented by Silva *et al.* (2013 WD; Figure 2.2).

No attempts to raise observed discard rates to fleet level have been undertaken as yet, and given the aggregating nature of spurdog, such analyses would need to be undertaken with care.

Further information on discards can be found in the Stock Annex.

2.3.3 Discard survival

Low mortality has been reported for spurdog caught by trawl when tow duration was < 1 h, with overall mortality of about 6% (Mandelman and Farrington, 2007; Rulifson, 2007), with higher levels of mortality (ca. 55%) reported for gillnet-caught spurdog (Rulifson, 2007).

Only limited data on at-vessel mortality are available for European waters (Bendall *et al.*, 2012), and there are no published data on post-release mortality.

2.3.4 Quality of the catch data

In addition to the problems associated with obtaining estimates of the historical total landings of spurdog, due to the use of generic dogfish landings categories, anecdotal information suggests that widespread misreporting by species may have contributed significantly to the uncertainties in the overall level of spurdog landings.

Underreporting may have occurred in certain ICES areas when vessels were trying to build up a track record of other species, for example deep-water species. It has also been suggested that over-reporting may have occurred in the case where other elasmobranch stocks with highly restrictive quotas have been recorded as spurdog. It is not possible to quantify the amount of under and over-reporting that may have occurred. The introduction of UK and Irish legislation requiring registration of all fish buyers and sellers should mean that such misreporting problems have declined since 2006.

It is not known whether the 5% bycatch ratio (implemented in 2008) or the maximum landing length (in 2009) led to misreporting (although the buyers and sellers legislation should deter this) or increased discarding.

Given the zero TAC in place, recent catch data are highly uncertain. Whilst data from discard observer programmes may allow catches to be estimated, the estimation of dead discards will be more problematic.

Some nations may now be reporting landings of spurdog under more generic codes (e.g. *Squalus* sp., Squalidae and Squaliformes) as well as for *Squalus acanthias*.

2.4 Commercial catch composition

2.4.1 Length composition of landings

Sex disaggregated length–frequency samples are available from UK (E&W) for the years 1983–2001 and UK (Scotland) for 1991–2004 for all gears combined. The Scottish length–frequency distributions appear to be quite different from the length–frequency distributions obtained from the UK (E&W) landings, with a much larger proportion of small females being landed by the Scottish fleets. Figure 2.2 shows landings length–frequency distributions averaged over five-year intervals. The Scottish data have been raised to total Scottish reported landings of spurdog while the UK (E&W) data have only been raised to the landings from the sampled boats, a procedure which is likely to mean that the latter length frequencies are not representative of total removals by the UK (E&W) fleet. For this reason, the UK (E&W) length frequencies are assumed to be representative only of the landings by the target fleet from this country.

Raw market sampling data were also provided by Scotland for the years 2005–2010. However, sampled numbers have been low in recent years (due to low landings) and use of these data was not pursued.

2.4.2 Length composition of discards

Discard length–frequency data were provided by the UK (Scotland) for 2010. Length frequencies raised to trip level and pooled over all trips and areas by gear type are shown in Figure 2.3. These have not been raised to fleet level.

Discard length–frequency data were provided by the UK (England) for four broad gear types (Figure 2.4). In general, beam trawlers caught relatively few spurdog, and these were comprised mostly of juveniles, gillnets catches were dominated by fish 60–90 cm TL and otter trawlers captured a broad length range. Data for larger fish sampled across the whole time-series were most extensive for gillnetters operating in the Celtic Seas (Silva *et al.,* 2013 WD). The discarding rates of commercial sized fish (80–100 cm TL) from these vessels increased from 7.5% (2002–2008) to 18.7% (2009–2010), whereas the proportion of fish > 100 cm LT discarded increased from 6.2% (2002–2008) to 34.1% (2009–2010), indicating an increased proportion of larger fish were discarded in line with the maximum landing length regulations that were in force during 2009–2010. The zero TAC with no bycatch allowance resulted in the discarding of all observed spurdog in 2011.

2.4.3 Sex ratio

No recent data.

2.4.4 Quality of data

Length–frequency samples were only available for UK landings and these were aggregated into broader length categories for the purpose of assessment. No data were available from Norway or Ireland, which were the other main nations exploiting this stock. For the 20 years prior to restrictive measures, UK landings accounted for approximately 45% of the total. However, there has been a systematic decline in this proportion since 2005 and the UK landings in 2008 represented 15% of the total. In 2010, UK landings were just above 5% of the total, and < 1% in 2011. It is not known to what extent the available commercial length–frequency samples are representative of the catches by these other nations. In addition, there are only limited length–frequency data from recent years.

From French on-board observation data, the occurrence of spurdog was calculated as the proportion of fishing operations (trawl haul or net set) with catch (discards, landings or both) of spurdog in areas where the species is observed regularly in French fisheries, namely Subarea 6 and divisions 7.b-c and 7.f-k from 2007–2015. Other areas, such as the Bay of Biscay (Subarea 8) where occurrences are rare in French Fisheries were excluded. Fishing operations were aggregated by DCF level 5 métier. The time-series of the proportion of fishing operations encountering spurdog is shown for the four top ranking métiers (Figure 2.36). No trend was observed in the two main métiers (OTB-DEF and OTT-DEF), with the two other métiers (with lower numbers of observed fishing operations) showing contrasting signals.

2.5 Commercial catch-effort data

No commercial CPUE data were available to the WG.

The outline of a Norwegian sentinel fishery on spurdog was presented to the 2012 WG (Albert and Vollen, 2012 WD). This potential provider of an abundance index series has not been initiated yet.

A UK Fishery Science Partnership (FSP) study carried out by CEFAS examined spurdog in the Irish Sea (Ellis *et al*., 2010), primarily to (a) evaluate the role of spurdog in longline fisheries and examine the catch rates and sizes of fish taken in a longline fishery; (b) provide biological samples so that more recent data on the length-at-maturity and fecundity can be calculated; and (c) tag and release a number of individuals to inform on the potential discard survivorship from longline fisheries. Survey stations were chosen by the fishermen participating in the survey.

This survey undertook studies on a commercial, inshore vessel that had traditionally longlined for spurdog during parts of the year. Four trips (nominally one in each quarter), each of four days, were undertaken over the course of the year. The spurdog caught were generally in good condition, although the bait stripper can damage the jaws, and those fish tagged and released were considered to be in a good state of health.

Large numbers of spurdog were caught during the first sampling trip, of which 217 were tagged with Petersen discs and released. The second sampling trip yielded few spurdog, although catches at that time of year are considered by fishermen to be sporadic. Spurdog were not observed on the first three days of the third trip, but reasonable numbers were captured on the last day, just off the Mull of Galloway. The fourth trip (spread over late October to early December, due to poor weather) yielded some reasonably large catches of spurdog from the grounds just off Anglesey.

2.6 Fishery-independent information

2.6.1 Availability of survey data

Fishery-independent survey data are available for most regions within the stock area. Beam trawl surveys are not considered appropriate for this species, due to the low catchability of spurdog in this gear type. The surveys coordinated by IBTS have higher catchability and the gears are considered suitable for this species. Spatial coverage of the North and Celtic Seas represents a large part of the stock range (Figure 2.5). For further details of these surveys and gears used see ICES (2010). The following survey data have been used in earlier analyses by WGEF:

- UK (England & Wales) Q1 Celtic Sea groundfish survey: years 1982–2002.
- UK (England & Wales) Q4 Celtic Sea groundfish survey: years 1983–1988.
- UK (England & Wales) Q3 North Sea groundfish survey 1977–present.
- UK (England & Wales) Q4 SWIBTS survey 2004–2009 in the Irish and Celtic Seas.
- UK (NI) Q1 Irish Sea groundfish survey 1992–2008.
- UK (NI) Q4 Irish Sea groundfish survey 1992–2008.
- Scottish Q1 west coast groundfish survey: years 1990–2010 (ScoGFS-WIBTS-Q1) and 2011–2015 (UKSGFS-WIBTS-Q1).
- Scottish Q4 west coast groundfish survey: years 1990–2009 (ScoGFS-WIBTS-Q4) and 2011–2015 (UKSGFS-WIBTS-Q4).
- Scottish Q1 North Sea groundfish survey: years 1990–2010.
- Scottish Q3 North Sea groundfish survey: years 1990–2009.
- Scottish Rockall haddock survey: years 1990–2009.
- Irish Q3 Celtic Seas groundfish survey: years 2003–2009.
- North Sea IBTS (NS-IBTS) survey: years 1977–2010.

A full description of the current groundfish surveys can be found in the Stock Annex.

Norwegian data on spurdog from the Shrimp survey (NO-shrimp-Q1) and the Coastal survey (NOcoast-Aco-Q4) were presented to the WGEF in 2014 and 2018 (Vollen, 2014 WD). The survey coverage is shown in Figure 2.6, and general information on the surveys can be found in Table 2.4.

The annual shrimp survey (1998–2020) covers the Skagerrak and the northern parts of the North Sea north to 60°N. The timing of the survey changed from quarter 4 (1984–2003), via quarter 3 (2002–2004), to quarter 1 from 2005. Mesh size was not specified for the first years, 35 mm from 1989–1997, and 20 mm from 1998. Trawl time was one hour from 1984–1989, then 30 minutes for later years.

The coastal survey (1996–2020) yearly covers the areas from 62°N to the Russian border in the north in October–November. Only data south of 66°N were used, as very few spurdog were caught north of this latitude. Length data were available from 1999 onwards. A Campelen Shrimp trawl with 40 mm mesh size was used from 1995–1998, whereas mesh size was 20 mm for later years. Trawl time was 20–30 minutes.

Spurdog catches in these surveys are not numerous. Number of stations with spurdog catches ranged from one to 35 per year in the shrimp survey; and from 0 to 8 per year in the coastal survey. The total number of spurdog caught ranged from one to 341 individuals per year in the shrimp survey, and from 0 to 106 individuals per year in the coastal survey (Table 2.4).

2.6.2 Length–frequency distributions

Length–frequency distributions (aggregated overall years) from the UK (E&W), Scottish and Irish groundfish surveys are shown in Figures 2.7–2.8.

The UK (E&W) groundfish survey length–frequency distribution (Figure 2.7a) consists of a high proportion of large females, although this is influenced by a single large catch of these individuals. Mature males are also taken regularly and juveniles often caught on the grounds in the northwestern Irish Sea.

The Irish Q4 GFS also catches some large females (Figure 2.7b), but the majority of individuals (both males and females) are of intermediate size, in the range 50–80 cm.

The Scottish West coast groundfish surveys demonstrate an almost complete absence of large females in their catches (Figure 2.8). These surveys show a high proportion of large males and also a much higher proportion of small individuals, particularly in the Q1 survey. However, it should be noted that length frequency distributions exhibit high variability from year to year (not shown) with a small number of extremely large hauls dominating the length–frequency data.

In the UK FSP survey, the length range of spurdog caught was 49–116 cm (Figure 2.9), with catches in Q1 and Q3 being mainly large (> 90 cm) females. Catches in Q4 yielded a greater proportion of smaller fish. The sex ratio of fish caught was heavily skewed towards females, with more than 99% of the spurdog caught in Q1 female. Although more males were found in Q3 and Q4, females were still dominant, accounting for 87% and 79% of the spurdog catch, respectively. Numerically, between 16.5 and 41.9% of spurdog captured were > 100 cm, the Maximum Landing Length in force at the time.

In the Norwegian Shrimp and Coastal surveys, the length–frequency distribution was rather uniform overall years, with the length groups 60–85 cm being the most abundant (Figure 2.10).

Previously presented length frequencies are displayed in the Stock Annex.

2.6.3 CPUE

Spurdog survey data are typically characterised by highly variable catch rates due to occasional large hauls and a significant proportion of zero catches.

Time-series plots of frequency of occurrence (proportion of non-zero hauls) for the Irish surveys are shown in Figure 2.12. This short time-series shows stability on the frequency of occurrence and on the catch rates. For UK surveys, previously presented data (either discontinued or not updated this year) have indicated a trend of decreasing occurrence and decreasing frequency of large catches with catch rates also decreasing (although highly variable) (Figures 2.16–2.17).

Time-series plots of frequency of occurrence (five year running mean) for both Norwegian surveys is shown for > 20 years in Figure 2.13; shrimp survey (1985–2018) and coastal survey (1995–2018). The frequency of occurrence declined for the Shrimp survey from late 1980s and reached a low in late 1990s. Since then, the Shrimp survey shows an increasing trend, whereas the Coastal survey shows a decreasing trend. With regards to average catch range, numbers are variable, but a decrease can be seen from the 1980s to the late 1990s for the Shrimp survey. For the Coastal survey, a peak could be seen around 2004, but it should be noted that results are generally based on very few stations.

Future studies of survey data could usefully examine surveys from other parts of the stock area, as well as sex-specific and juvenile abundance trends. In the absence of accurate catch data, fishery-independent trawl surveys will be increasingly important to monitor stock recovery.

2.6.4 Statistical modelling

At the 2006 WG meeting, an analysis of Scottish survey data was presented, which investigated methods for standardizing the survey catch rate with the aim obtaining an appropriate index of abundance. Following on from this, and the subsequent comments of the Review Group, further analysis was conducted in 2009 to provide an index of biomass catch rates rather than abundance in N.hr-1. As at previous WG meetings a biomass index was derived from an analysis of Scottish survey data.

Data from four Scottish surveys listed above (1990–2019) were considered in the analysis (Rockall was not included due to the very low numbers of individuals caught in this survey). The dataset consists of length–frequency distributions at each trawl station (almost 8000 in total), together with the associated information on gear type, haul time, depth, duration and location. For each haul station, catch-rate was calculated: total weight caught (derived from length using the length-weight relationship) divided by the haul duration to obtain a measure of catch-per-unit of effort in terms of g/30 minutes.

The objective of the analysis was to obtain standardized annual indices of CPUE (on which an index of relative abundance can be based) by identifying explanatory variables which help to explain the variation in catch rate and which is not a consequence of changes in population size. Due to the highly skewed distribution of catch rates and the presence of the large number of zeros, a 'delta' distribution approach was taken to the statistical modelling. Lo *et al.*, 1992 and Stefansson, 1996 describe this method which combines two generalized linear models (GLM): one which models the probability of a positive observation (binomial model) and the second which models the catch rate conditioned on it being positive assuming a lognormal distribution. The overall year effect (annual index) can then be calculated by multiplying the year effects estimated by the two models.

The aim of the analysis was to obtain an index of temporal changes in CPUE and therefore year was always included as a covariate (factor) in the model. Other explanatory variables included were area (Scottish demersal sampling area, see Dobby et al. (2005) for further details) and month or quarter. Variables which explained greater than 5% of the deviance in previous analysis were retained in the model. All variables were included as categorical variables.

The model results, in terms of retained terms and deviance values are presented in Table 2.5. Estimated effects are shown in Figure 2.18. The diagnostic plot for the final lognormal model fit is shown in Figure 2.19, indicating that the distributional assumptions are adequate: the residuals show a relatively symmetrical distribution, with no obvious departures from normality, and the residual variance shows no significant changes through the range of fitted values.

The estimated year effects for the binomial component of the model demonstrate a significant decline over the overall first part of the time period with an increase in more recent years. The year effects for the catch rate given that it is positive show a generally increasing trend since around 2006. Although this index is used within the assessment, there are a number of issues associated with the analysis which should be highlighted:

- The survey data analysed only covers a proportion of the stock distribution (Division 6.a and the northern North Sea);
- The two Scottish west coast surveys underwent a redesign in 2011, including the use of new ground-gear. No consideration has been given to potential changes in catchability due to the new ground-gear in this analysis.
- A sex-disaggregated index would potentially be more informative.

The upcoming benchmark represents an opportunity to explore additional survey data and alternative approaches to modelling data containing a high proportion of zeros.

2.7 Life-history information

Maturity and fecundity data were collected on the UK FSP surveys (Ellis et al, 2010). The largest immature female spurdog was 84 cm, with the smallest mature female 78 cm. The smallest mature and active female observed was 82 cm. All females ≥ 90 cm were mature and active. The observed uterine fecundity was 2–16 pups, and larger females produced more pups. In Q1, the embryos were either in the length range 11–12 cm or 14–18 cm, and no females exhibited signs of recently having given birth. In Q3, near-term pups were observed at lengths of 16–21 cm. During Q4, near-term and term pups of 19–24 cm were observed, and several females showed signs of recently having pupped. This further suggests that the Irish Sea may be an important region in which spurdog give birth during late autumn and early winter, although it is unclear if there are particular sites in the area that are important for pupping.

Collection of biological data for *S. acanthias* was possible as part of a Defra-funded project aiming to better understand the implications of elasmobranch bycatch in the southwest fisheries around the British Isles (Silva and Ellis, 2015 WD). A total of 1112 specimens were examined, including 805 males (53–92 cm LT) and 307 females (47–122 cm LT), as well as associated pups (n = 935, 98–296 mm LT). Conversion factors were calculated for the overall relationships between total length and total weight by sex and maturity stage and gutted weight by sex only.

Preliminary results suggested there may be no changes of length-at-maturity of females in comparison to earlier estimates of Holden and Meadows (1962), indicating that this life-history parameter may not have changed in relation to recent overexploitation. However, the maximum fecundity observed (n = 19 pups) reported in this recent study is higher than reported in earlier studies (e.g. Ford, 1921; Holden and Meadows, 1964; Gauld, 1979), and provides further support to the hypothesis that there has been a density-dependent increase in fecundity (see Ellis and Keable, 2008 and references therein).

Updated life history data have also been collected (Albert *et al.*, 2019; see Section 2.14), which should be investigated for any update to the benchmark assessment.

The biological parameters currently used in the assessment can be found in the Stock Annex.

2.8 Exploratory assessments and previous analyses

2.8.1 Previous assessments

Exploratory assessments undertaken in 2006 included the use of a delta-lognormal GLM-standardized index of abundance and a population dynamic model. This has been updated at subsequent meetings. The results from these assessments indicate that spurdog abundance has declined, and that the decline is driven by high exploitation levels in the past, coupled with biological characteristics that make this species particularly vulnerable to such intense exploitation (ICES, 2006).

2.8.2 Simulation of effects of maximum landing length regulations

Earlier demographic studies on elasmobranchs indicate that low fishing mortality on mature females may be beneficial to population growth rates (Cortés, 1999; Simpfendorfer, 1999). Hence, measures that afford protection to mature females may be an important element of a management plan for the species. As with many elasmobranchs, female spurdog attain a larger size than males, and larger females are more fecund.

Preliminary simulation studies of various Maximum Landing Length (MLL) scenarios were undertaken by ICES (2006) and suggested that there are strong potential benefits to the stock by protecting mature females. However, improved estimates of discard survivorship from various commercial gears are required to better examine the efficacy of such measures.

2.9 Stock assessment

2.9.1 Introduction

A benchmark assessment of the model was carried out in 2011. A summary of review comments and response to it were provided in Appendix 2a of the 2011 WGEF report (ICES, 2011), and is reproduced in an Appendix to the Stock Annex. The model is described in detail in the Stock Annex, and in De Oliveira *et al*. (2013).

In 2011, WGEF updated the model based on the benchmark assessment. Subsequent update assessments were carried out in 2014, 2016 and 2018, and the results presented here are for a further update to include data up to 2019.

The 2018 ADGEF expressed their concern about the constant catch assumption after the moratorium (2010+). This concern was discussed during the 2020 WGEF whereby the group decided to present two assessments reflecting alternative assumptions about the catch in the moratorium period to the 2020 ADGEF (ICES, 2020). One assessment reflects the constant catch scenario set at the average landings for 2007–2009 (C_{SQ})and a second assessment assumes a constant harvest rate set at the average harvest rate for 2007–2009 (HR_{SQ}), which is considered to be a more realistic approach. The 2020 ADGEF decided to go with the same approach as used in previous assessments, i.e. the constant catch scenario approach because this was viewed as the most accurate information on catch, as most of it is bycatch. In addition, no change in the basis of the advice was preferred as the stock would be due for a full benchmark in 2021.

Life-history parameters and input data

Calculation of the life-history parameters M_a (instantaneous natural mortality rate), l_a^s (mean length-at-age for animals of sex *s*), w_a^s (mean weight-at-age for animals of sex *s*), and P_a'' (proportion females of age a that become pregnant each year) are summarised in Table 2.6, and described visually in Figure 2.20.

Landings data used in the assessment are given in Tables 2.7a and b. Two assessments have been prepared, one with a constant catch assumption for 2010+ (as assumed in previous years) and one assuming the harvest rate has been constant since 2010 (which is likely to be a more realistic assumption); the difference in catches between these two scenarios are shown in Table 2.7b. The assessment requires the definition of fleets with corresponding exploitation patterns, and the only information currently available to provide this comes from Scottish and English & Wales databases. Two fleets, a “non-target” fleet (Scottish data) and a “target” fleet (England & Wales data), were therefore defined and allocated to landings data. Several targeting scenarios were explored in order to show the sensitivity of model results to these allocations (ICES, 2011), and these results are included here. In order to take the model back to a virgin state, the average proportion of these fleets for 1980–1984 were used to split landings data prior to 1980, but two of the targeting scenarios assume historic landings were only from “non-target” or “target” fleets.

The Scottish survey abundance index (biomass catch rate) was derived on the basis of applying a delta-lognormal GLM model to four Scottish surveys over the period 1990–2019, and is given in Table 2.8 along with the corresponding CVs. The proportions-by-length category data derived from these surveys, along with the actual sample sizes these data are based on, are given in Table 2.9 separately for females and males.

Table 2.10 lists the proportion-by-length-category data for the two commercial fleets considered in the assessment, along with the raised sample sizes. Because these raised sample sizes do not necessarily reflect the actual sample sizes the data are based on (as they have been raised to landings), these sample sizes have been ignored in the assessment (by setting $n_{pcom,j,y} = \bar{n}_{pcom,j}$ in equation 10b of the Stock Annex); a sensitivity test conducted in ICES (2010) showed a lack of sensitivity to this assumption.

The fecundity data (see Ellis and Keable, 2008, for sampling details) are given as pairs of values reflecting length of pregnant female and corresponding number of pups, and are listed in tables 2.11a and b for the two periods (1960 and 2005).

2.9.2 Summary of model runs in WGEF 2020

Category	Description	Figures	Tables
Base case run	Results presented for two assessments, differing by the assumption made about catches for 2010+: C_{SQ} assumes constant catches at the average landings for 2007-2009 HR_{SQ} assumes constant harvest rate at the average harvest rate for 2007-2009 All results (apart from Figure 2.30) are reported for these two assessments	2.21–27, 2.31–33	2.12–15
Retrospective	A 6-year retrospective analysis, using the base case run and omitting one year of data each time	2.28	
Sensitivity			
Q_{fec}	A comparison with an alternative Q_{fec} values that fall within the 95% probability interval of Figure 2.21, with a demonstration of the deterioration in model fit to the survey abundance index for higher Q_{fec} values	2.22, 2.29	
Targeting scenarios	A comparison of alternative assumptions about targeting (taken from ICES, 2011): Tar 1: the base case (each nation is defined “non-target”, “target” or a mixture of these, with pre-1980s allocated the average for 1980–1984) Tar 2: as for WGEF in 2010 (Scottish landings are “non-target”, E&W “target”, and the remainder raised in proportion to the Scottish/E&W landings, with pre-1980s allocated the average for 1980–1984) Tar 3: as for Tar 2 but with E&W split 50% “non-target” and 50% “target” Tar 4: as for Tar 1, but with pre-1980 selection entirely non-target Tar 5: as for Tar 1, but with pre-1980 selection entirely target	2.30	

2.9.3 Results for base case run

Model fits

Two assessments have been prepared, one with a constant catch assumption for 2010+ (as assumed in previous years; taken as the average catch 2007-9) and one assuming the harvest rate has been constant since 2010 (average harvest rate 2007–9, which is likely to be a more realistic assumption). Therefore, all plots and tables reflect these two assessments, and they are distinguished in figure and table captions by the labels “C_{SQ}” (constant catch assumption for 2010+) and “HR_{SQ}” (constant harvest rate assumption for 2010+).

Fecundity data available for two periods present an opportunity to estimate the extent of density-dependence in pup-production (Q_{fec}). However, estimating this parameter along with the fecundity parameters a_{fec} and b_{fec} for the two time-periods was not possible because these parameters are confounded. The approach therefore was to plot the likelihood surface for a range of fixed a_{fec} and b_{fec} input values, while estimating Q_{fec}, and the results are shown in Figure 2.21. The two periods of fecundity data are essential for the estimation of Q_{fec}, and further information that would help with the estimation of this parameter would be useful. Figure 2.21d indicates a near-linear relationship between Q_{fec} and $MSYR$ (defined in terms of the biomass of all animals $\geq l^{f}_{mat00}$), so additional information about $MSYR$ levels typical for this species could be used for this purpose (but has not yet been attempted).

The value of Q_{fec} chosen for the base case run (2.149 for both C_{SQ} and HR_{SQ} assessments) corresponded to the lower bound of the 95% probability interval shown in Figures 2.21a and b. Lower Q_{fec} values correspond to lower productivity, so this lower bound is more conservative than other values in the probability interval. Furthermore, sensitivity tests in the past had shown that higher Q_{fec} values were associated with a deterioration in the model fit to the Scottish survey abundance index, but this appears no longer to be the case (Figure 2.22), and will be investigated at the forthcoming benchmark meeting.

Figures 2.22a and b show the model fit to the Scottish surveys abundance index for the base case value of Q_{fec} and for alternative values that still fall within the 95% confidence interval in plot c of Figures 2.21a and b. Figures 2.23a and c show the model fit to the Scottish and England & Wales commercial proportion-by-length-category data, and Figures 2.23b and d the model fit to the Scottish survey proportion-by-length-category data, the latter fitted separately for females and males. Model fits to the survey index and commercial proportion data appear to be reasonably good with no obvious residual patterns, and a close fit to the average proportion-by-length-category for the commercial fleets. Figures 2.23b and d indicate a poorer fit to the survey of sex proportions compared to the commercial proportions, but given the residual patterns (a dominance of positive residuals for females, and, more weakly, the opposite for males) it may be possible to estimate sex ratio (to be investigated during the forthcoming benchmark).

Figures 2.24a and b compare the deterministic and stochastic modelled recruitment, and plot the estimated normalised recruitment residuals. The model fits of the two periods of fecundity data are shown in Figures 2.25a and b, highlighting the difference in the fecundity relationship with female length for the two periods (1960 and 2005), this difference being due to Q_{fec}.

Estimated parameters

Model estimates of the total number of pregnant females in the virgin population ($N_0^{f,preg}$), the extent of density-dependence in pup production (Q_{fec}), survey catchability (q_{sur}), and current (2020) total biomass levels relative to 1905 and 1955 (B_{depl05} and B_{depl55}), are shown in Tables 2.12a and c (for the "base case" and alternative Q_{fec} values) together with estimates of precision. Estimates of the natural mortality parameter M_{pup}, the fecundity parameters a_{fec} and b_{fec}, and MSY parameters ($F_{prop,MSY}$, MSY, B_{MSY}, MSY $B_{trigger}$ and $MSYR$) are given in Tables 2.12b and d. Tables 2.13a and b provide a correlation matrix for some of the key estimable parameters (only the last five years of recruitment deviations are shown). Correlations between estimable parameters are generally low, apart from the commercial selectivity parameters associated with length categories 55–69 cm and 70–84 cm, and Q_{fec} vs. q_{sur}.

Estimated commercial- and selectivity-at-age patterns are shown in Figures 2.26a and b, and reflect the relatively lower proportion of large animals in the survey data when compared to the commercial catch data, and the higher proportion of smaller animals in the Scottish commercial catch data compared to England & Wales (see also Figures 2.23a-d). It should be noted that females grow to larger lengths than males, so that females are able to grow out of the second highest length category, whereas males, with an L_∞ of < 85 cm (Table 2.6) are not able to do so (hence the commercial selectivity remains unchanged for the two largest length categories for males). The divergence of survey selectivity for females compared to males is a reflection of the separate selectivity parameters for females/males in the largest length category (70+ for surveys).

A plot of recruitment vs. the number of pregnant females in the population, effectively a stock–recruit plot, is given in plot b of Figures 2.24a and b together with the replacement line (the number of recruiting pups needed to replace the pregnant female population under no harvesting). This plot illustrates the importance of the Q_{fec} parameter in the model: a Q_{fec} parameter equal to 1 would imply the expected value of the stock–recruit point lies on the replacement line, which implies that the population is effectively incapable of replacing itself. A further exploration of the behaviour of Q_y and $N_{pup,y}$ (equations 2a and b in the Stock Annex) is shown in Figures 2.27a and b.

Time-series trends

Model estimates of total biomass (By) and mean fishing proportion (Fprop5-30,y) are shown in Figures 2.32a and b together with observed annual catch ($C_y = \sum_j C_{j,y}$). They indicate a strong decline in spurdog total biomass, particularly since the 1940s, to a low around the mid-2000s (19% of pre-exploitation levels), which appears to be driven by relatively high exploitation levels, given the biological characteristics of spurdog. $F_{prop5\text{-}30,y}$ appears to have declined in recent years, with B_y increasing again to 27% of pre-exploitation levels in 2020 (Bdepl05 in Tables 2.12a and c). Figures 2.32a and b also show total biomass (B_y), recruitment (R_y) and mean fishing proportion ($F_{prop5\text{-}30,y}$) together with approximate 95% probability intervals. The fluctuations in recruitment towards the end of the time-series are driven by information in the proportion-by-length-category data. Tables 2.14a and b provide a stock summary (recruitment, total biomass, landings and $F_{prop5\text{-}30,y}$).

2.9.4 Retrospective analysis

A six year retrospective analysis (the base case model was re-run, each time omitting a further year in the data) was performed, and is shown in Figures 2.28a and b for the total biomass (B_y), mean fishing proportion ($F_{prop5\text{-}30,y}$) and recruitment (R_y). A retrospective pattern appears to have developed since the 2016 assessment (see ICES, 2016). Although a worrying development (to be investigated at the forthcoming benchmark), the retrospective patterns are still well within the 95% confidence limits of the assessments estimates (compare Figures 2.28a and b with Figure 2.32a and b, respectively), Mohn's rho metrics are all less than 0.2 in absolute terms (these metrics are given in the plots of Figures 2.28a and b), and the retrospective pattern is in the conservative direction (underestimating stock size and overestimating fishing pressure), so not an immediate concern.

2.9.5 Sensitivity analyses

Two sets of sensitivity analyses were carried out, as listed in the text table above.

a) Q_{fec}

The a_{fec} and b_{fec} values that provided the lower bound of the 95% probability interval (Q_{fec}=2.149; plots a-c in Figures 2.21a and b) was selected for the base case run. This sensitivity test compares it to the runs for which the a_{fec} and b_{fec} input values provide the optimum (C_{SQ}: Q_{fec}=2.629) and upper bound (C_{SQ}: Q_{fec}=3.792). Model result are fairly sensitive to these options (Figures 2.29a and b, Tables 2.12a–d). A part justification for selecting the more conservative lower bound as the base case value was a deterioration in the fit to the Scottish survey abundance index as Qfec values increase, but this seems no longer to be the case and needs further exploration during the forthcoming benchmark meeting.

b) Alternative targeting scenarios

Alternatives targeting scenarios for both the post-1980s landings data (for which data are available by nation) and the pre-1980s landings data (not available by nation) were explored in this set of sensitivity analyses presented in ICES (2011) and shown again here. The alternative scenarios are listed in Section 2.9.2, and results shown in Figure 2.30. These results indicate a general lack of sensitivity to alternative assumptions about targeting.

2.9.6 MSY $B_{trigger}$

As with surplus production models such as SPiCT, the spurdog assessment estimates reference points each time the assessment is run (see Stock Annex). The current estimates of B_{MSY} for spurdog is 947 895 t for the C_{SQ} assessment ("Base case" in Tables 2.12b). According to ICES guidelines (ICES, 2017), MSY $B_{trigger}$ represents the 5th percentile of the distribution of B_{MSY} in cases where B_{MSY} is estimable and has been "observed" by the assessment; this is indeed the case for spurdog (with the model stretching back to the virgin state), so we approximate the 5th percentile of the B_{MSY} distribution by setting MSY $B_{trigger}$ = B_{MSY}/1.4 (see second bullet on page 16 of ICES, 2017, for the approach). This leads to an MSY $B_{trigger}$ value of 677 068 t for the assessments.

2.9.7 Projections

The base case assessment (see Tables 2.12) is used as a basis for future projections under a variety of catch options. These are based on:

- The ICES MSY rule, which assumes that $F_{prop,MSY}$ = 0.033 and *MSY* $B_{trigger}$ = 677 068 t (Tables 2.12b and Section 2.9.6; this rule fishes at $F_{prop,MSY}$ = 0.033 for total biomass values at or above *MSY* $B_{trigger}$, but reduces fishing linearly when total biomass is below *MSY* $B_{trigger}$ by the extent to which total biomass is below *MSY* $B_{trigger}$);
- Zero catch (for comparison purposes);
- TAC_{2009} = 1422 t, the last non-zero TAC set for spurdog in 2009;
- C_{SQ}: average landings for 2007–2009 = 2468 tan amount that could accommodate bycatch in mixed fisheries;
- Fishing at $F_{prop,MSY}$ = 0.033 (the MSY harvest rate).

Results are given in Tables 2.15a , expressed as total biomass in future relative to the total biomass in 2020, and are illustrated in Figures 2.31. Results relative to MSY $B_{trigger}$ are given in Tables 2.15b . Recovery to MSY $B_{trigger}$ for the most conservative catch options (zero, TAC 2009, ave. catch 2007–9) from 2020 are 16, 18 and 19 years, with the remaining options (MSY approach and MSY harvest rate) taking longer than 30 years (point estimates in Tables 2.15b).

2.9.8 Conclusion

In 2020, WGEF presented two assessments; the base case which uses a constant catch assumption for 2010+ (as assumed in previous years; taken as the average catch 2007–9: C_{SQ}), and one assuming the harvest rate has been constant since 2010 (at the average harvest rate 2007-: HR_{SQ}) (ICES, 2020). At the 2020 ADG, the base case model (C_{SQ}) was chosen as the final assessment to provide advice. The main reason for this was to keep the basis to the advice similar given the, at that time, expected 2021 benchmark (WKNSEA, ICES 2021).

Although the base case assessment (C_{SQ}) has a retrospective pattern, which first surfaced at the last assessment (ICES, 2018), it is still well within the 95% confidence limits of the assessment, with absolute Mohn's rho values less than 0.2, and the model provides reasonable fits to most of the available data. Sensitivity tests show the model to be sensitive to the range of Q_{fec} values that fall within the 95% probability interval for corresponding fecundity parameters, and the conservative choice of Q_{fec} at the lower end of the 95% confidence limits for this parameter needs to be re-assessed at the forthcoming benchmark meeting. The model is relatively insensitive to alternative targeting scenarios, including assumptions about selection patterns prior to 1980. Summary plot of the final assessments (the base case run), showing landings and estimates of recruitment, mean fishing proportion (with F_{prop}, MSY = 0.033) and total biomass (with MSY

$B_{trigger}$ = 677 068 t), together with estimates of precision, are given in Figures 2.32a and b and Tables 2.14a and b.

Results from the current model confirm that spurdog abundance has declined, and that the decline is driven by high exploitation levels in the past, coupled with biological characteristics that make this species particularly vulnerable to such intense exploitation. The assessment also confirms that the stock is starting to recover from a low in the mid-2000s.

A comparison with the 2018 assessment is provided in Figures 2.33a and d and shows a slight upward adjustment in recruitment and total biomass in recent years.

2.10 Quality of assessments

WGEF has attempted various analytical assessments of NE Atlantic spurdog using a number of different approaches (see Stock Annex and ICES, 2006). Although these exploratory models did not prove satisfactory (as a consequence of the quality of the assessment input data), they all indicated a decline in spurdog, as did previous analyses of survey data.

Whilst the current assessment model has been both benchmarked and published, there are a number of issues to consider, as summarised below.

2.10.1 Catch data

The WG has provided estimates of total landings of NE Atlantic spurdog and has used these, together with UK length–frequency distributions in the assessment of this stock. However, there are still concerns over the quality of these data as a consequence of:

- Uncertainty in the historical level of catches because of landings being reported by generic dogfish categories;
- Uncertainty over the accuracy of the landings data because of species misreporting;
- Lack of commercial length–frequency information for countries other than the UK (UK landings are a decreasing proportion of the total and therefore the length frequencies may not be representative of those from the fishery as a whole);
- Low levels of sampling of UK landings and lack of length–frequency data in recent years when the selection pattern may have changed due to the implementation of a maximum landing length (100 cm);
- Lack of discard information.

2.10.2 Survey data

Survey data are particularly important indicators of abundance trends in stocks such as this where an analytical assessment is not available. However, it should be highlighted that:

- The survey data used by WGEF cover only part of the stock distribution and analyses should be extended to other parts of the stock distribution;
- Spurdog survey data are difficult to interpret because of the typically highly skewed distribution of catch-per-unit of effort;
- Annual survey length–frequency distribution data (aggregated over all hauls) may be dominated by data from single large haul.

2.10.3 Biological information

As well as good commercial and survey data, the analytical assessments require good information on the biology of NE Atlantic spurdog. In particular, the WG would like to highlight the need for:

- Updated and validated age and growth parameters, in particular for larger individuals;
- Better estimates of natural mortality.

2.10.4 Assessment

As with any stock assessment model, the assessment relies heavily on the underlying assumptions; particularly with regard to life-history parameters (e.g. natural mortality and growth), and on the quality and appropriateness of input data. The inclusion of two periods of fecundity data has provided valuable information that allows estimation of Q_{fec}, and projecting the model back in time is needed to allow the 1960 fecundity dataset to be fitted. Nevertheless, the model has difficulty estimating both Q_{fec} and the fecundity parameters simultaneously, and additional information, such as on appropriate values of *MSYR* for a species such as spurdog, and possibly also additional fecundity data (which are now available but have not been included), would help with this problem. Further refinements of the model are possible, such as including variation in growth. Selectivity curves also cover a range of gears over the entire catch history, and more appropriate assumptions (depending on available data) could be considered. A check should be kept on the recent development of a retrospective pattern, although this is still well within the 95% confidence limits of assessment estimates, with absolute Mohn's rho values less than 0.2.

In summary, the model is considered appropriate for providing an assessment of spurdog, though the availability and applicability of the following data were examined during the 2021 benchmark (WKNSEA, ICES 2021):

- Selectivity parameters disaggregated by gear for the main fisheries (i.e. for various trawl, longline and gillnets);
- Appropriate indices of relative abundance from fishery-independent surveys, with corresponding estimates of variance;
- Improved estimates for biological data (e.g. growth parameters, reproductive biology and natural mortality);
- Inclusion of additional fecundity data;
- Information on likely values of *MSYR* for a species such as spurdog.

2.11 Reference points

As with surplus production models such as SPiCT, the spurdog assessment estimates reference points each time the assessment is run (see Stock Annex).

MSY considerations: In 2020, the exploitation status of the stock was considered to be below $F_{prop,MSY}$, as estimated from the results of the assessment. However, biomass has declined to record low levels in recent years, and therefore to allow the stock to rebuild, catches should be reduced to the lowest possible level in 2021 and 2022. Projections assuming application of the average landings for 2007–9 (C_{SQ}) (which would accommodate bycatch in mixed fisheries) suggest that the stock will rebuild by 5–10% of its 2020 level by 2023 (Table 2.15a).

$F_{prop,MSY}$ = 0.033, as estimated by the current assessment, assuming a non-target selection pattern.

2.12 Benchmark 2021

In February 2021, a benchmark for spurdog was held as part of WKNSEA (ICES 2021).

Summary of the benchmark:

The **spurdog** assessment is the only elasmobranch category 1 assessment with an integrated age–length-based assessment that includes catch data back to 1905. Survey indices included in the assessment only covered a relatively small part (primarily divisions 6.a and 4.a) of the entire stock distribution area. As such, one of the main aims of the benchmark was to improve spatial coverage by including a number of eligible surveys in the assessment. Further, the inclusion of new fecundity data along with improved information on growth was on the issue list. Finally, inclusion of fleet-based data (including length distributions), and better catch information since 2010 was to be addressed and a data-call was set up to request this information. Four main topics were considered in this benchmark (i) catch data (landings, discards and commercial size and sex composition), (ii) survey indices (biomass indices and size and sex composition), (iii) biological parameters, and (iv) reference points.

Based on the discussion on spatial and temporal coverage of the various surveys in DATRAS and those made available as part of the data call, the workshop agreed to derive three separate biomass indices, one per quarter (Q1, Q3, Q4). Data extraction and manipulation made use of the 'DATRAS' R package while statistical modelling has been carried out using the 'surveyIndex' R package (Berg et al., 2014). It implements a GAM modelling framework allowing for a variety of different model assumptions including 'delta' models with lognormal and gamma distributions for positive observations. In addition to the survey indices (and estimated CVs), the number of individuals by sex (sample size) and proportion at length by year (and sex) were calculated for use in the stock assessment. Details on the input data, analysis and results are found in the WD by Dobby (2021). This results in the following indices to be used in the assessment:

- A modelled Q1 index by sex, based on four survey time-series: NO-SH, NS-IBTS, SWC-IBTS, SCOWCGFS [1985–present].
- Q3 index by sex, based on a single survey: NS-IBTS [1992–present]
- A modelled Q4 index by sex, based on five survey time-series: SWC-IBTS, SCOWCGFS, NIGFS, IE-IGFS, EVHOE [2003–present].

Fecundity data used to inform the model were improved from having two data years (1960, 2005) to include 13 data years covering the time period 1921–2020.

For reference points B_{lim} was set to 20% of B0 as the model goes back to 1905 were reporting of landings were relatively low and well before the high exploitation in the 1950s and onwards. For detailed descriptions, please see the benchmark report ICES, 2021. Note that the first stock assessment following this benchmark will be done in 2021 and this chapter will be updated accordingly.

2.13 Conservation considerations

In 2007, the IUCN world redlist categorized Northeast Atlantic spurdog as 'Vulnerable', although the most recent assessment of spurdog in European waters lists spurdog as 'Endangered' (Nieto *et al.*, 2015).

2.14 Management considerations

Perception of state of stock

All analyses presented in previous reports of WGEF have indicated that the NE Atlantic stock of spurdog declined over the second half of the 20th century, but now appears to be increasing. The current stock size is thought to be ca. 24% of virgin biomass.

Although spurdog are less frequently caught in groundfish surveys than they were 20 years ago, there is some suggestion that spurdog are now being more frequently seen in survey hauls, and survey catch rates are starting to increase (Figure 2.12).

Stock distribution

Spurdog in the ICES area are considered to be a single stock, ranging primarily from Subarea 1 to Subarea 8, although landings from the southern end of its range may also include other *Squalus* species.

Biological considerations

Spurdog is a long-lived and slow growing species which has a high age-at-maturity and is particularly vulnerable to high levels of fishing mortality. Furthermore, females are thought to have restricted movement (Thorburn *et al.*, 2015). Population productivity is low, with low fecundity and a protracted gestation period. In addition, they form size- and sex-specific shoals and therefore aggregations of large fish (i.e. mature females) are easily exploited by target longline and gillnet fisheries.

Updated age and growth studies are required. For Norwegian waters, see Albert *et al.*, 2019 and Section 2.14.

Fishery and technical considerations

Those fixed gear fisheries that capture spurdog should be reviewed to examine the catch composition, and those taking a large proportion of mature females should be strictly regulated.

During 2009 and 2010, a maximum landing length (MLL) was established in EC waters to deter targeting of mature females (see Section 2.10 of ICES, 2006 for simulations on MLL). Those fisheries taking spurdog that are lively may have problems measuring fish accurately, and investigations to determine an alternative measurement (e.g. pre-oral length) that has a high correlation with total length and is more easily measured on live fish are required. Dead spurdog may also be more easily stretched on measuring, and understanding such post-mortem changes is required to inform on any levels of tolerance, in terms of enforcement.

There is limited information on the distribution of gravid females with term pups and new-born spurdog pups, though they have been reported to occur in Scottish waters, in the Celtic Sea and off Ireland. The lack of accurate data on the location of pupping and nursery grounds, and their importance to the stock, precludes spatial management for this species at the present time.

2.15 Additional recent information

2.15.1 Developing an abundance index for spurdog in Norwegian waters

Input data to the assessment model have so far been restricted to the British sector, and data from other areas have been requested. In Norwegian waters, from where more than 80% of the current landings originate, there is no dedicated survey for spurdog, but data are recorded on all regular surveys, as well as by the Norwegian Reference fleet, and during official controls of commercial catches and landings. Two WDs were presented at 2016 WGEF meeting to indicate the potential for establishing one or several new tuning fleets in Norwegian waters to inform future assessments of this stock. An update was presented at 2020 WGEF.

Here are shown the updated trends from the Shrimp Survey in South-Norway (divisions 3.a and 4.a), the Coastal Survey in North-Norway (Division 2.a) and from samples from the commercial fleet in Norwegian waters. Details of the calculations were given in Albert and Vollen (2015 WD), Albert (2016 WD), Vollen and Albert (2016 WD), and Junge *et al*. (2020 WD).

The Shrimp Survey shows a rather clear pattern, with relatively high and fluctuating survey indices in the 1980s, low and decreasing values throughout the 1990s, reaching the lowest values in 2002, and then a return to high and variable values since 2003 (Figure 2.34; updated in Figure 2.14 and shown in strata in Figure 2.15). The Coastal Survey shows highly variable survey indices, with slight tendencies of higher values between 2000–2010 than in both the preceding and the following years (Figure 2.34). The percent of occurrence of spurdog in sampled catches from Norwegian commercial gillnetters shows an increasing trend throughout the most recent decade, and similar trends are also present from some other fleets (Figure 2.35).

All of these time series are crude estimates without proper stratification, and should only be regarded as preliminary indications of overall trends. Before the next benchmarking process of spurdog, more elaborated indices of abundance and composition should preferably be documented for this northern part of the distribution range.

2.15.2 Recent life-history information

The most recent update of biological data for *S. acanthias* in the North East Atlantic are from Norwegian waters (Albert *et al*., 2019). A total of 3948 bycaught individuals were sampled throughout the period from 2014–2018, within the ICES divisions 2.a, 4.a, and 3.a. Overall, females accounted for 56% of the samples, but the sex compositions of individual catches were highly skewed.

The sampled spurdog varied in length from 41 to 95 cm and 53 to 121 cm for males and females, respectively. The mean lengths of both males and females were larger in the northern area of the study.

The age composition was similar for both sexes, observed from the age of 3 up to the med-30s with dominance of individuals <15 years of age. Median age for both sexes was 11 years, with an interquartile range of 9–14 and 8–17 for females and males, respectively.

The youngest and smallest mature females were 7 years and 68 cm, while the oldest and largest immature ones were 26 years and 100 cm. Mean age of late gravid females was 15.3 years, with an interquartile range of 12–16 years; estimated 50% maturity was 9.5 years and 77.8 cm. For males, very few immatures were recorded making estimation of 50% maturity uncertain.

Near-term females had a range of 1–19 pups and a mean of 7.2 pups. Difference between left and right uteri was a maximum of two pups for 92% of the near-term females. Mean pup length of near-term females was 24 cm, with 10 and 90 percentiles of 19 and 27 cm, respectively. Both the number and mean size of pups of near-term females increased with maternal length.

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Table 2.1. Northeast Atlantic spurdog. WG estimates of total landings of NE Atlantic spurdog (1947–2020).

Year	Landings (tonnes)	Year	Landings (tonnes)	Year	Landings (tonnes)
1947	16 893	1972	50 416	1997	15 347
1948	19 491	1973	49 412	1998	13 919
1949	23 010	1974	45 684	1999	12 384
1950	24 750	1975	44 119	2000	15 890
1951	35 301	1976	44 064	2001	16 693
1952	40 550	1977	42 252	2002	11 020
1953	38 206	1978	47 235	2003	12 246
1954	40 570	1979	38 201	2004	9 365
1955	43 127	1980	40 968	2005	7 101
1956	46 951	1981	39 961	2006	4 015
1957	45 570	1982	32 402	2007	2 917
1958	50 394	1983	37 046	2008	1 798
1959	47 394	1984	35 193	2009	1 980
1960	53 997	1985	38 674	2010	893
1961	57 721	1986	30 910	2011	435
1962	57 256	1987	42 355	2012	453
1963	62 288	1988	35 569	2013	336
1964	60 146	1989	30 278	2014	383
1965	49 336	1990	29 906	2015	263
1966	42 713	1991	29 562	2016	373
1967	44 116	1992	29 046	2017	296
1968	56 043	1993	25 636	2018	363
1969	52 074	1994	20 851	2019	455
1970	47 557	1995	21 318	2020	526
1971	45 653	1996	17 294		

Table 2.2. Northeast Atlantic spurdog. WG estimates of total landings by nation (1980–2019); "-" = no data available, "." = zero catch, "+" = <0.5 tonnes Data from 2005 onwards revised during WKSHARK2. From 2005 Scottish landings data are combined with those from England and Wales, and presented as UK (combined).

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Belgium	1097	1085	1110	1072	1139	920	1048	979	657	750	582	393	447	335	396	391
Denmark	1404	1418	1282	1533	1217	1628	1008	1395	1495	1086	1364	1246	799	486	212	146
Faroe Islands	0	22	0	0	0	0	0	0	0	6	2	3	25	137	203	310
France	17 514	19 067	12 430	12 641	8356	8867	7022	11 174	7872	5993	4570	4370	4908	4831	3329	1978
Germany	43	42	39	25	8	22	41	48	27	24	26	6	55	8	21	100
Iceland	36	22	14	25	5	9	7	5	4	17	15	53	185	108	97	166
Ireland	108	476	1268	4658	6930	8791	5012	8706	5612	3063	1543	1036	1150	2167	3624	3056
Netherlands	217	268	183	315	0	0	0	0	0	0	0	0	0	0	0	0
Norway	5925	3941	3992	4659	4279	3487	2986	3614	4139	5329	8104	9633	7113	6945	4546	3940
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	2	0	0	0	0	0	1	5	3	2	128	188	250	323	190	256
Russia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	8	653	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	399	308	398	300	256	360	471	702	733	613	390	333	230	188	95	104
UK (E&W)	9229	9342	8024	6794	8046	7841	7047	7684	6952	5371	5414	3770	4207	3494	3462	2354
UK (Sc)	4994	3970	3654	4371	4957	6749	6267	8043	8075	8024	7768	8531	9677	6614	4676	8517
Total	40 968	39 961	32 402	37 046	35 193	38 674	30 910	42 355	35 569	30 278	29 906	29562	29046	25636	20851	21318

Table 2.2 (continued). Northeast Atlantic spurdog. WG estimates of total landings by nation (1980–2019); “-” = no data available, “.” = zero catch, “+” = <0.5 tonnes Data from 2005 onwards revised during WKSHARK2. From 2005 Scottish landings data are combined with those from England and Wales, and presented as UK (combined)

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Belgium	430	443	382	354	400	410	23	11	13	21	17	11	12	7	1	0	0	0	-	-
Denmark	142	196	126	131	146	156	107	232	219	150	121	76	78	82	14	26	30	19	10	27
Faroe Islands	51	218	362	486	368	613	340	224	295	225	271	241	144	462	179	104	-	-	-	-
France	1607	1555	1286	998	4342	4304	2569	1705	1062	946	702	505	368	412	164	84	34	13	19	2
Germany	38	21	31	54	194	304	121	98	138	140	7	3	5	2	1	1	1	1	1	+
Iceland	156	106	80	57	107	199	276	200	142	76	82	43	68	102	62	53	51	6	19	8
Ireland	2305	2214	1164	904	905	1227	1214	1416	1076	1022	859	651	137	175	26	13	37	34	18	2
Netherlands	0	0	0	0	28	39	27	10	25	31	23	25	18	5	7	1	4	3	0	1
Norway	2748	1567	1293	1461	1643	1424	1091	1119	1054	1016	790	615	711	543	540	247	285	250	313	217
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	120	100	46	21	2	3	4	4	9	5	9	10	4	3	2	3	2	2	1	2
Russia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	28	95	372	363	306	135	17	43	47	85	42	23	7	7	6	2	1	4
Sweden	154	196	140	114	123	238	0	275	244	169	147	93	75	80	5	0	-	-	-	-
UK (combined)*	2670	3066	4480	4461	3654	4516	2823	3109	1729	3481	1209	799	280	546	64	1	3	6	0	-
UK (Sc)*	6873	5665	4501	3248	3606	2897	2120	3708	3342											
Total	17 294	15 347	13 919	12 384	15 890	16 693	11 020	12 246	9365	7101	4015	2917	1798	1980	893	435	453	336	383	263

Table 2.2 (continued). Northeast Atlantic spurdog. WG estimates of total landings by nation (1980–2020); "-" = no data available, "." = zero catch, "+" = <0.5 tonnes. Data from 2005 onwards revised during WKSHARK2. From 2005 Scottish landings data are combined with those from England and Wales, and presented as UK (combined).

Country	2016	2017	2018	2019	2020
Belgium	-	-	-	-	
Denmark	24	27	19	21	32
Faroe Islands	-	-	-	-	-
France	1	3	1	-	-
Germany	2	+	1	+	-
Iceland	8	4	2	1	3
Ireland	34	1	24	11	3
Netherlands	1	1	6	+	+
Norway	270	222	271	370	409
Poland	-	-	-	-	-
Portugal	1	1	1	.	-
Russia	-	-	-	-	-
Spain	1	.	.	-	+
Sweden	+	+	+	+	-
UK (combined)*	30	37	38	52	79
UK (Sc)*					
Total	373	296	363	455	526

Table 2.3. Northeast Atlantic spurdog. WG estimates of landings by ICES Subarea (1980–2019). Data from 2005 onwards revised during WKSHARK2.

Subarea or Division	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Baltic	0	0	0	0	0	0	0	1	0	0	0	1	3	0	0	0	0	0
1 and 2	138	20	28	760	40	120	137	417	1559	2808	4296	6614	5063	5102	3124	2725	1853	582
3 and 4	20 544	16 181	11 965	11 572	10 557	11 136	8986	11 653	10 800	10 423	11 497	9264	10 505	6591	4360	7347	5299	4977
5	45	27	18	27	5	22	9	41	6	73	182	133	336	335	364	484	217	320
6	4590	4011	5052	7007	8491	12422	8107	9038	7517	6406	5407	6741	6268	5927	5622	5164	4168	3412
7.a	2722	4013	4566	4001	6336	6774	6458	7305	5569	3389	2801	2527	2669	2700	2313	1185	1650	1534
7.b-c	704	925	424	1777	2178	1699	1197	2401	1579	893	369	293	316	2009	1175	1004	603	450
7.d-f	6693	8210	5989	4664	2450	1280	1644	2892	2120	1634	1339	1122	852	785	800	760	852	646
7.g-k	4793	5479	3881	6924	4902	4965	3864	8106	6175	4477	3736	2495	2622	1745	2680	2034	2229	2984
8	739	1095	479	312	234	257	507	497	242	174	273	367	406	435	406	602	408	418
9	0	0	0	0	0	0	1	4	1	2	4	4	2	5	7	5	2	2
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	12
14	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0
Other or unspecified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	12	10
Total	40 968	39 961	32 402	37 046	35 193	38 674	30 910	42 355	35 569	30 278	29 906	29 562	29 046	25 636	20 851	21 318	17 294	15 347

Table 2.3 (continued) Northeast Atlantic spurdog. WG estimates of landings by ICES Subarea (1980–2019). Data from 2005 onwards revised during WKSHARK2.

Subarea or Division	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Baltic	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 and 2	607	779	894	462	357	440	423	682	499	312	337	230	190	93	131	74	122	105
3 and 4	3895	2705	2475	2516	1904	2395	2163	1177	789	628	642	635	400	183	189	198	203	140
5	442	545	879	1406	808	583	677	244	204	161	86	103	63	53	51	6	28	8
6	2831	2715	5977	5624	3169	3398	2630	1581	830	619	169	263	69	3	1	0	0	+0
7.a	1771	2153	1599	1878	1529	2021	938	589	413	272	73	97	3	1	10	4	2	+
7.b-c	854	1037	1028	816	527	588	432	332	268	299	48	97	7	1	1	0	0	0
7.d-f	443	411	438	555	295	268	278	285	168	172	124	196	78	71	33	17	8	+
7.g-k	2656	1822	2161	2846	2130	2339	1739	2005	746	386	245	288	63	14	29	30	16	2
8	308	171	405	469	269	134	56	138	87	58	70	65	15	12	3	3	2	2
9	2	3	19	8	11	5	14	5	10	11	5	6	5	5	5	3	2	6
10	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	104	22	14	41	22	74	12	4	1	0	0	0	0	0	0	0	0	0
14	0	0	0	63	0	0	0											
Other or unspecified	6	4	1	2	0	0	0	59	0	0	0	0	0	0	0	0	0	0
Total	13 919	12 384	15 890	16 693	11 020	12 246	9365	7101	4015	2917	1798	1980	893	435	453	336	383	263

Table 2.3 (continued) Northeast Atlantic spurdog. WG estimates of landings by ICES Subarea (1980–2020). Data from 2005 onwards revised during WKSHARK2.

Subarea or Division	2016	2017	2018	2019	2020
Baltic	0	0	0	0	0
1 and 2	150	127	164	183	280
3 and 4	165	123	128	208	156
5	8	4	2	0	3
6	5	1	3	0	5
7.a	2	0	+	+	+
7.b-c	3	0	0	0	0
7.d-f	1	14	19	14	28
7.g-k	36	24	45	49	53
8	1	1	+	0	+
9	2	1	1	0	0
10	0	0	0	0	0
12	0	0	0	0	0
14	0	0	1	0	0
Other or unspecified	0	0	0	0	0
Total	373	296	363	455	526

Table 2.4. Northeast Atlantic spurdog. Norwegian Shrimp and Coastal survey, 1984–2017. Month of survey, mean duration of tows, total number of stations, number of stations with spurdog, total number of spurdog caught, and mesh size used. Source: Vollen and Albert (2016 WD).

Year	Survey	Month of survey	Mean duration (h)	# of stations	# of stations with spurdog	# spurdogs caught	Mesh size	Survey	Month of survey	Mean duration (h)	# of stations	# of stations with spurdog	# spurdogs caught	Mesh shze
1984	S	10–11	0.96	59	10	67								
1985	S	10–11	1.00	86	29	303								
1986	S	10–11	0.96	57	26	341								
1987	S	10–11	0.99	93	29	90								
1988	S	10–11	0.97	102	29	87								
1989	S	10–11	0.50	89	11	18	35							
1990	S	10–11	0.49	77	19	130	35							
1991	S	10–11	0.52	101	11	38	35							
1992	S	10–11	0.50	99	12	22	35							
1993	S	10–11	0.50	106	10	14	35							
1994	S	10–11	0.47	101	10	18	35							
1995	S	10–11	0.48	102	8	15	35	C	9–10	0.43	29	6	22	40
1996	S	10–11	0.50	103	4	15	35	C	9–10	0.45	22	5	9	40
1997	S	10–11	0.49	93	10	18	35	C	8–9	0.42	44	1	2	20
1998	S	10–11	0.49	95	9	14	20	C	10–11	0.47	33	8	106	20
1999	S	10–11	0.50	97	4	7	20	C	10–11	0.44	34	2	4	20
2000	S	10–11	0.50	98	5	18	20	C	10–11	0.47	28	6	12	20
2001	S	10–11	0.50	70	2	3	20	C	10–11	0.42	17	5	64	20
2002	S	10–11	0.50	77	1	1	20	C	10–11	0.46	37	4	43	20
2003	S	10–11	0.53	68	12	34	20	C	10–11	0.44	23	4	21	20
2004	S	5–6	0.50	60	7	48	20	C	10–11	0.37	33	5	104	20
2005	S	5–6	0.51	86	7	12	20	C	10–11	0.46	18	2	17	20
2006	S	1–2	0.49	43	9	33	20	C	10–11	0.30	34	8	52	20
2007	S	1–2	0.50	64	14	27	20	C	10–11	0.35	36	7	35	20
2008	S	1–2	0.51	73	13	52	20	C	10–11	0.56	7	0	0	20
2009	S	1–2	0.47	92	16	39	20	C	10–11	0.39	19	0	0	20
2010	S	1–2	0.47	95	20	34	20	C	10–11	0.36	26	3	25	20
2011	S	1–2	0.49	97	18	43	20	C	10–11	0.33	20	5	6	20
2012	S	1–2	0.47	63	14	71	20	C	10–11	0.36	31	5	9	20
2013	S	1–2	0.38	100	35	177	20	C	10	0.42	19	1	1	20
2014	S	1	0.47	68	18	99	20	C	10	0.39	30	3	4	20
2015	S	1	0.49	88	18	62	20	C	10-11	0.37	28	5	10	20
2016	S	1	0.50	105	19	51	20	C	10	0.37	27	2	37	20
2017	S	1	0.50	108	35	90	20	C	10-11	0.41	33	3	26	20

Table 2.5. Northeast Atlantic spurdog. Analysis of Scottish survey data. Summary of significance of terms in final delta-lognormal CPUE model.

Binomial model	Df	Deviance	Resid df	Resid dev	%	P(>|Chi|)
			7794	8767.4		
as.factor(year)	29	103.93	7765	8663.4	5%	2.28E-10
as.factor(month)	11	1284.25	7754	7379.2	66%	< 2.2e-16
as.factor(roundarea)	19	564.68	7735	6814.5	29%	< 2.2e-16

Lognormal model	Df	Deviance	Resid df	Resid dev	%	Pr(>F)
			1948	5783.1		
as.factor(year)	29	339.65	1919	5443.5	31%	2.52E-15
as.factor(Q)	3	476.72	1916	4966.8	44%	< 2.2e-16
as.factor(roundarea)	17	263.38	1899	4703.4	24%	1.69E-14

Table 2.6. Northeast Atlantic spurdog. Description of life-history equations and parameters.

Parameters	Description/values	Sources
M_a	Instantaneous natural mortality at age *a*: $M_a = \begin{cases} M_{pup} e^{-a \ln(M_{pup}/M_{adult})/a_{M1}} & a < a_{M1} \\ M_{adult} & a_{M1} \le a \le a_{M2} \\ M_{til} / [1 + e^{-M_{gam}(a-(A+a_{M2})/2)}] & a > a_{M2} \end{cases}$	
a_{M1} , a_{M2}	4, 30	expert opinion
M_{adult} , M_{til} , M_{gam}	0.1, 0.3, 0.04621	expert opinion
M_{pup}	Calculated to satisfy balance equation 2.7	
l_a^s	Mean length-at-age a for animals of sex *s* $l_a^s = L_\infty^s (1 - e^{-\kappa^s (a - t_0^s)})$	
L_∞^f , L_∞^m	110.66, 81.36	average from literature
κ^f , κ^m	0.086, 0.17	average from literature
t_0^f , t_0^m	-3.306, -2.166	average from literature
w_a^s	Mean weight at age *a* for animals of sex *s* $w_a^s = a^s (l_a^s)^{b^s}$	
a^f , b^f	0.00108, 3.301	Bedford *et al*. (1986)
a^m , b^m	0.00576, 2.89	Coull *et al*. (1989)
l_{mat00}^f	Female length at first maturity 70 cm	average from literature
P''_a	Proportion females of age a that become pregnant each year $P''_a = \dfrac{P''_{\max}}{1 + \exp\left[-\ln(19)\dfrac{l_a^f - l_{mat50}^f}{l_{mat95}^f - l_{mat50}^f}\right]}$ where $P''_{\max}$ is the proportion very large females pregnant each year, and l_{matx}^f the length at which *x*% of the maximum proportion of females are pregnant each year	
$P''_{\max}$	0.5	average from literature
l_{mat50}^f , l_{mat95}^f	80 cm, 87 cm	average from literature

Table 2.7a. Northeast Atlantic spurdog. Landings used in the assessment (1905-2009), with the allocation to "Non-target" and "Target". Estimated Scottish selectivity (based on fits to proportions by length category data for the period 1991–2004) is assumed to represent "non-target" fisheries, and estimated England and Wales selectivity (based on fits to proportions by length category data for the period 1983–2001) "target" fisheries. The allocation to "Non-target" and "Target" shown below is based on categorising each nation as having fisheries that are "non-target", "target" or a mixture of these from 1980 onwards. An average for the period 1980–1984 is assumed for the "non-target"/"target" split prior to 1980, while all landings from 2008 onwards are assumed to come from "non-target" fisheries. Landings are used as catch in the assessment.

Year	Non-target	Target	Total	Year	Non-target	Target	Total	Year	Non-target	Target	Total
1905	3503	3745	7248	**1940**	4556	4872	9428	**1975**	21322	22797	44119
1906	1063	1137	2200	**1941**	4224	4516	8740	**1976**	21295	22769	44064
1907	690	738	1428	**1942**	5135	5490	10625	**1977**	20420	21832	42252
1908	681	728	1409	**1943**	3954	4227	8181	**1978**	22828	24407	47235
1909	977	1045	2022	**1944**	3939	4212	8151	**1979**	18462	19739	38201
1910	755	808	1563	**1945**	3275	3501	6776	**1980**	20770	20198	40968
1911	946	1011	1957	**1946**	5265	5630	10895	**1981**	20953	19009	39962
1912	1546	1653	3199	**1947**	8164	8729	16893	**1982**	16075	16327	32402
1913	1957	2093	4050	**1948**	9420	10071	19491	**1983**	17095	19951	37046
1914	1276	1365	2641	**1949**	11120	11890	23010	**1984**	15047	20147	35194
1915	1258	1344	2602	**1950**	11961	12789	24750	**1985**	17048	21626	38674
1916	258	276	534	**1951**	17060	18241	35301	**1986**	15138	15772	30910
1917	164	175	339	**1952**	19597	20953	40550	**1987**	19558	22798	42356
1918	218	233	451	**1953**	18464	19742	38206	**1988**	17292	18277	35569
1919	1285	1374	2659	**1954**	19607	20963	40570	**1989**	15355	14924	30279
1920	2125	2271	4396	**1955**	20843	22284	43127	**1990**	14390	15516	29906
1921	2572	2749	5321	**1956**	22691	24260	46951	**1991**	14034	15529	29563
1922	2610	2791	5401	**1957**	22023	23547	45570	**1992**	15711	13335	29046
1923	2733	2922	5655	**1958**	24355	26039	50394	**1993**	12268	13369	25637
1924	3071	3284	6355	**1959**	22905	24489	47394	**1994**	9238	11613	20851
1925	3247	3472	6719	**1960**	26096	27901	53997	**1995**	12104	9214	21318
1926	3517	3760	7277	**1961**	27896	29825	57721	**1996**	10026	7269	17295
1927	4057	4338	8395	**1962**	27671	29585	57256	**1997**	9158	6190	15348
1928	4602	4920	9522	**1963**	30103	32185	62288	**1998**	8509	5410	13919
1929	4504	4816	9320	**1964**	29068	31078	60146	**1999**	7233	5152	12385
1930	5758	6156	11914	**1965**	23843	25493	49336	**2000**	9283	6608	15891
1931	5721	6117	11838	**1966**	20642	22071	42713	**2001**	9513	7180	16693
1932	8083	8643	16726	**1967**	21320	22796	44116	**2002**	6169	5001	11170
1933	9784	10460	20244	**1968**	27085	28958	56043	**2003**	7167	5080	12247
1934	9848	10530	20378	**1969**	25166	26908	52074	**2004**	5718	3648	9366
1935	10761	11505	22266	**1970**	22983	24574	47557	**2005**	4234	4192	8426
1936	10113	10812	20925	**1971**	22063	23590	45653	**2006**	2670	1439	4109
1937	11565	12365	23930	**1972**	24365	26051	50416	**2007**	1846	1083	2929
1938	8794	9402	18196	**1973**	23880	25532	49412	**2008**	1836	0	1836
1939	9723	10396	20119	**1974**	22078	23606	45684	**2009**	2640	0	2640

Table 2.7b. Northeast Atlantic spurdog. Landings from 2010 onwards used in the assessment, with the allocation to "Non-target" and "Target" (see caption to Table 2.7a for more details). Landings from 2010 onwards are assumed to be either the average landings for 2007–2009 (left) or the average harvest rate for 2007–2009 (right). Landings are used as catch in the assessment.

Constant catch (ave 2007–2009)				Constant harvest rate (ave 2007–2009)			
Year	**Non-target**	**Target**	**Total**	**Year**	**Non-target**	**Target**	**Total**
2010	2468	0	2468	**2010**	2716	0	2716
2011	2468	0	2468	**2011**	2777	0	2777
2012	2468	0	2468	**2012**	2842	0	2842
2013	2468	0	2468	**2013**	2914	0	2914
2014	2468	0	2468	**2014**	2992	0	2992
2015	2468	0	2468	**2015**	3071	0	3071
2016	2468	0	2468	**2016**	3145	0	3145
2017	2468	0	2468	**2017**	3221	0	3221
2018	2468	0	2468	**2018**	3307	0	3307
2019	2468	0	2468	**2019**	3386	0	3386

Table 2.8. Northeast Atlantic spurdog. Delta-lognormal GLM-standardised index of abundance (with associated CVs), based on Scottish groundfish surveys.

Year	Index	CV
1990	156.8	0.31
1991	91.3	0.30
1992	78.4	0.30
1993	145.5	0.30
1994	128.5	0.33
1995	50.3	0.45
1996	86.1	0.33
1997	52.9	0.33
1998	82.4	0.33
1999	176.4	0.31
2000	75.5	0.34
2001	96.0	0.32
2002	96.4	0.31
2003	90.1	0.33
2004	64.4	0.35
2005	79.4	0.34
2006	63.6	0.33
2007	87.1	0.30
2008	76.1	0.33
2009	63.2	0.34
2010	86.1	0.45
2011	86.8	0.36
2012	72.9	0.36
2013	71.6	0.37
2014	159.5	0.31
2015	63.6	0.36
2016	153.1	0.31
2017	202.3	0.31
2018	127.9	0.33
2019	204.3	0.30

Table 2.9. Northeast Atlantic spurdog. Scottish survey proportions-by-length category for females (top) and males (bottom), with the actual sample sizes given in the second column.

	$n_{psur,y}$	16–31	32–54	55–69	70+
Females					
1990	539	0.0112	0.2685	0.1265	0.1272
1991	962	0.0636	0.1218	0.1092	0.1123
1992	145	0.1430	0.1514	0.2055	0.0424
1993	398	0.1259	0.1635	0.0788	0.1296
1994	1656	0.0744	0.2426	0.0519	0.0352
1995	2278	0.0572	0.3087	0.0779	0.1520
1996	230	0.0722	0.2381	0.0831	0.0684
1997	167	0.0438	0.2011	0.0955	0.0815
1998	446	0.0361	0.2404	0.1201	0.1731
1999	186	0.0316	0.0787	0.0331	0.1079
2000	1994	0.0962	0.2136	0.0456	0.1149
2001	118	0.0132	0.2060	0.0735	0.1363
2002	148	0.0428	0.0789	0.1773	0.1879
2003	224	0.0123	0.1578	0.0788	0.1898
2004	63	0.0412	0.0834	0.1240	0.0597
2005	121	0.0243	0.1434	0.1568	0.0756
2006	92	0.0360	0.1130	0.1727	0.0413
2007	152	0.0287	0.1773	0.1075	0.1657
2008	232	0.0708	0.1590	0.0127	0.1047
2009	233	0.0427	0.1175	0.2547	0.1167
2010	3495	0.1787	0.2687	0.1127	0.0002
2011	130	0.0183	0.1565	0.0684	0.1812
2012	808	0.0364	0.2320	0.0855	0.1316
2013	65	0.1713	0.2228	0.0146	0.1513
2014	608	0.0463	0.1701	0.0848	0.0873
2015	139	0.0535	0.1617	0.1744	0.1353
2016	670	0.0975	0.1383	0.1383	0.1456
2017	941	0.0758	0.1728	0.0817	0.1280
2018	275	0.0431	0.0882	0.1718	0.1165
2019	1439	0.0182	0.2127	0.0652	0.2199
Males					
1990	1044	0.0204	0.1300	0.0575	0.2587
1991	1452	0.0711	0.1273	0.0824	0.3123
1992	154	0.2324	0.0534	0.0504	0.1215
1993	644	0.0503	0.1202	0.1555	0.1762
1994	2467	0.0832	0.1809	0.1472	0.1847
1995	1905	0.0566	0.1259	0.0478	0.1738
1996	453	0.0597	0.1480	0.1237	0.2068

	$n_{psur,y}$	16–31	32–54	55–69	70+
1997	270	0.0228	0.1033	0.0803	0.3716
1998	436	0.0207	0.0974	0.0969	0.2155
1999	2045	0.0100	0.1144	0.0799	0.3255
2000	221	0.0141	0.1045	0.0753	0.3771
2001	264	0.0252	0.0654	0.1209	0.3016
2002	392	0.0209	0.0818	0.1257	0.3328
2003	190	0.0045	0.1397	0.1250	0.4225
2004	225	0.0297	0.0572	0.1506	0.3622
2005	180	0.0846	0.0992	0.1027	0.3505
2006	264	0.0044	0.1786	0.1423	0.1954
2007	395	0.0699	0.1482	0.0669	0.3678
2008	417	0.0252	0.1247	0.0719	0.2466
2009	2478	0.0028	0.1863	0.0644	0.1861
2010	567	0.0170	0.0896	0.0836	0.3853
2011	1278	0.0434	0.1249	0.0495	0.2968
2012	59	0.0242	0.1673	0.0639	0.1847
2013	1438	0.0463	0.1412	0.0668	0.3572
2014	207	0.0069	0.1532	0.0973	0.2177
2015	1095	0.0733	0.1134	0.1014	0.1922
2016	1581	0.0717	0.1194	0.1082	0.2423
2017	726	0.0534	0.1228	0.0579	0.3462

Table 2.10. Northeast Atlantic spurdog. Commercial proportions-by-length category (males and females combined), for each of the two fleets (Scottish, England & Wales), with raised sample sizes given in the second column.

	$n_{pcom,j,y}$	16–54	55–69	70–84	85+
Non-target (Scottish) commercial proportions					
1991	6167824	0.0186	0.4014	0.5397	0.0404
1992	6104263	0.0172	0.1844	0.7713	0.0272
1993	4295057	0.0020	0.2637	0.7106	0.0236
1994	3257630	0.0301	0.3322	0.5857	0.0520
1995	5710863	0.0112	0.2700	0.6878	0.0309
1996	2372069	0.0069	0.4373	0.5416	0.0142
1997	3769327	0.0091	0.3297	0.5909	0.0702
1998	3021371	0.0330	0.4059	0.5286	0.0325
1999	1869109	0.0145	0.3508	0.5792	0.0556
2000	1856169	0.00001	0.1351	0.7683	0.0967
2001	1580296	0.0021	0.2426	0.7022	0.0531
2002	1264383	0.0529	0.3106	0.5180	0.1186
2003	1695860	0.0011	0.2673	0.5729	0.1587
2004	1688197	0.0106	0.2292	0.6893	0.0708
Target (England & Wales) commercial proportion					
1983	243794	0.0181	0.4010	0.4778	0.1030
1984	147964	0.0071	0.2940	0.4631	0.2359
1985	97418	0.0015	0.1679	0.6238	0.2068
1986	63890	0.0004	0.1110	0.6410	0.2476
1987	116136	0.0027	0.1729	0.5881	0.2362
1988	168995	0.0085	0.0973	0.5611	0.3332
1989	109139	0.0011	0.0817	0.5416	0.3757
1990	39426	0.0168	0.1349	0.5369	0.3115
1991	42902	0.0013	0.1039	0.5312	0.3637
1992	23024	0.0003	0.1136	0.4847	0.4013
1993	15855	0.0012	0.1741	0.4917	0.3331
1994	14279	0.0026	0.2547	0.3813	0.3614
1995	48515	0.0007	0.1939	0.4676	0.3378
1996	16254	0.0082	0.3258	0.4258	0.2402
1997	22149	0.0032	0.1323	0.4082	0.4563
1998	21026	0.0007	0.1075	0.4682	0.4236
1999	9596	0.0037	0.1521	0.5591	0.2851
2000	10185	0.0001	0.0729	0.4791	0.4480
2001	17404	0.0024	0.1112	0.4735	0.4128

Table 2.11a. Northeast Atlantic spurdog. Fecundity data for 1960 (Ellis and Keable, 2008), given as length of pregnant female (l f) and number of pups (P'). Total number of samples is 783.

l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'
73	3	84	4	86	3	87	7	88	3	89	4	90	1	91	7	93	3	94	5	96	10	101	11
73	3	84	6	86	3	87	8	88	5	89	4	90	3	91	8	93	4	94	5	96	10	101	7
75	3	84	6	86	3	87	9	88	5	89	5	90	3	91	8	93	5	94	6	96	7	102	5
77	3	84	3	86	4	87	2	88	6	89	7	90	5	91	3	93	5	94	6	96	7	102	10
78	3	84	3	86	4	87	5	88	6	89	8	90	6	91	4	93	5	94	7	96	8	102	3
79	2	84	4	86	4	87	5	88	6	89	8	90	8	91	4	93	5	94	8	97	4	103	14
79	3	84	4	86	4	87	5	88	7	89	5	90	5	91	7	93	5	94	8	97	4	103	9
79	4	84	4	86	5	87	5	88	8	89	6	90	6	91	4	93	6	94	8	97	7	103	15
79	4	84	5	86	5	87	6	88	6	89	6	90	6	91	5	93	8	94	9	97	2	103	9
79	3	84	6	86	5	87	5	88	6	89	8	90	7	91	7	93	9	94	9	97	3	103	15
80	4	84	6	86	5	87	5	88	8	90	1	90	7	91	7	93	5	94	9	97	3	105	11
80	3	84	4	86	6	87	6	88	9	90	2	90	9	91	8	93	5	94	11	97	3	110	8
80	4	84	4	86	2	87	7	89	3	90	3	90	10	92	2	93	5	94	3	97	4	117	9
80	5	84	6	86	3	87	7	89	3	90	3	91	2	92	4	93	6	94	3	97	4		
80	2	84	6	86	4	87	7	89	4	90	3	91	3	92	5	93	6	94	8	97	4		
80	3	84	6	86	4	87	8	89	4	90	3	91	4	92	7	93	6	94	9	97	5		
80	3	84	6	86	5	87	9	89	4	90	5	91	5	92	2	93	8	94	9	97	6		
80	5	84	3	86	5	88	2	89	6	90	5	91	5	92	2	93	9	94	9	97	6		
81	1	84	4	86	5	88	2	89	2	90	5	91	6	92	2	93	9	94	11	97	7		
81	3	84	4	86	5	88	2	89	2	90	6	91	6	92	2	93	4	95	3	97	3		
81	3	84	4	86	6	88	4	89	3	90	7	91	7	92	2	93	6	95	6	97	5		
81	3	84	6	86	6	88	4	89	3	90	1	91	2	92	2	93	6	95	6	97	6		
81	6	84	6	86	7	88	5	89	3	90	2	91	2	92	3	93	6	95	8	97	7		
81	3	84	6	86	5	88	5	89	3	90	2	91	2	92	3	93	7	95	3	97	4		
81	3	84	6	86	6	88	5	89	3	90	3	91	2	92	3	93	9	95	4	97	6		
82	3	85	3	86	7	88	5	89	3	90	3	91	2	92	3	93	9	95	4	97	8		
82	4	85	3	86	7	88	6	89	4	90	3	91	3	92	3	93	9	95	4	97	9		
82	4	85	4	86	7	88	1	89	4	90	3	91	3	92	4	93	9	95	5	97	9		
82	4	85	5	86	8	88	2	89	4	90	4	91	4	92	4	93	9	95	7	97	4		
82	5	85	5	86	1	88	3	89	4	90	4	91	4	92	5	93	10	95	7	97	6		
82	6	85	5	86	2	88	3	89	4	90	4	91	4	92	5	93	11	95	7	97	7		
82	1	85	5	86	2	88	3	89	4	90	4	91	4	92	6	93	1	95	9	97	7		
82	4	85	5	86	3	88	3	89	4	90	4	91	4	92	6	93	4	95	6	97	9		
82	4	85	7	86	4	88	3	89	4	90	4	91	4	92	6	93	7	95	9	97	6		
82	6	85	1	86	5	88	3	89	4	90	5	91	4	92	6	93	4	95	7	97	8		
82	6	85	3	86	6	88	4	89	4	90	5	91	5	92	7	93	6	95	8	97	9		
82	5	85	3	86	7	88	4	89	5	90	5	91	5	92	7	93	6	95	10	98	1		
82	6	85	3	86	7	88	4	89	5	90	5	91	5	92	8	93	6	95	11	98	5		
82	5	85	4	86	7	88	4	89	5	90	5	91	5	92	9	93	7	95	11	98	6		
82	6	85	4	86	8	88	5	89	5	90	6	91	6	92	4	93	9	95	11	98	9		
82	5	85	4	87	2	88	5	89	5	90	6	91	6	92	5	93	9	95	4	98	9		
83	3	85	5	87	3	88	5	89	5	90	6	91	6	92	6	93	9	95	7	98	8		
83	2	85	5	87	4	88	5	89	6	90	8	91	6	92	6	93	9	95	8	98	8		
83	2	85	3	87	5	88	5	89	6	90	9	91	6	92	6	93	10	95	11	98	9		
83	3	85	4	87	6	88	5	89	6	90	4	91	7	92	7	93	11	95	11	98	12		
83	4	85	4	87	3	88	5	89	6	90	4	91	7	92	8	94	5	95	11	98	8		
83	5	85	5	87	4	88	5	89	6	90	4	91	7	92	6	94	6	96	4	98	8		
83	4	85	5	87	4	88	6	89	6	90	5	91	7	92	6	94	6	96	4	98	9		
83	4	85	5	87	4	88	6	89	7	90	5	91	4	92	7	94	6	96	9	99	6		
83	5	85	6	87	5	88	6	89	4	90	5	91	4	92	10	94	7	96	4	99	6		
83	5	85	6	87	5	88	6	89	4	90	6	91	4	92	3	94	9	96	5	99	8		
83	5	85	6	87	5	88	6	89	4	90	6	91	4	92	3	94	3	96	5	99	4		
83	6	85	7	87	7	88	6	89	4	90	6	91	4	92	4	94	3	96	5	99	8		
83	4	85	4	87	3	88	4	89	4	90	6	91	5	92	5	94	3	96	5	99	15		
83	4	85	5	87	4	88	5	89	4	90	7	91	6	92	6	94	4	96	6	99	8		
83	4	85	7	87	5	88	5	89	5	90	7	91	6	92	6	94	4	96	6	100	6		
83	6	85	8	87	5	88	5	89	5	90	7	91	6	92	7	94	4	96	6	100	9		
83	4	85	3	87	5	88	6	89	6	90	7	91	6	92	7	94	5	96	6	100	10		
83	4	85	4	87	6	88	6	89	6	90	9	91	6	92	7	94	5	96	8	100	14		
83	4	85	5	87	6	88	6	89	6	90	9	91	7	92	10	94	5	96	5	100	7		
83	6	85	6	87	7	88	5	89	6	90	5	91	7	92	6	94	6	96	5	100	10		
84	3	85	7	87	7	88	5	89	7	90	6	91	7	93	1	94	6	96	6	100	14		

l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'
84	3	85	4	87	7	88	6	89	3	90	6	91	8	93	4	94	6	96	6	101	4		
84	3	86	2	87	5	88	6	89	5	90	6	91	8	93	5	94	7	96	8	101	6		
84	4	86	3	87	5	88	6	89	6	90	7	91	8	93	6	94	7	96	8	101	6		
84	6	86	3	87	5	88	6	89	6	90	7	91	8	93	7	94	7	96	7	101	10		
84	3	86	4	87	6	88	7	89	8	90	8	91	4	93	8	94	7	96	7	101	7		
84	3	86	5	87	6	88	8	89	8	90	9	91	5	93	1	94	7	96	8	101	9		
84	3	86	2	87	7	88	8	89	3	90	10	91	7	93	2	94	8	96	10	101	11		
84	4	86	2	87	7	88	9	89	3	90	1	91	7	93	2	94	4	96	10	101	9		

Table 2.11b. Northeast Atlantic spurdog. Fecundity data for 2005 (Ellis and Keable, 2008), given as length of pregnant female (l f) and number of pups (P'). Total number of samples is 179.

l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'	l^f	P'
84	6	92	9	94	11	97	5	98	12	100	7	101	14	102	13	103	11	105	16	107	11	109	18
87	8	92	5	95	7	97	12	98	7	100	12	101	9	102	12	103	11	105	15	107	12	109	13
89	6	92	8	95	9	97	7	98	13	100	11	101	14	102	13	103	11	105	15	107	15	109	16
89	6	92	9	95	10	97	12	98	13	100	12	101	10	102	5	103	16	105	5	107	16	110	15
89	5	92	3	95	11	97	14	98	10	100	8	101	10	102	13	104	14	105	16	107	17	110	10
89	3	93	5	96	11	97	14	98	7	100	9	101	10	102	12	104	11	105	19	107	12	110	13
89	8	93	3	96	10	97	7	98	12	100	10	101	12	102	17	104	12	105	11	108	16	111	19
89	5	93	9	96	7	97	7	98	12	100	9	102	17	102	13	104	14	105	8	108	13	112	17
90	9	93	4	96	7	98	12	98	10	100	9	102	3	103	14	104	14	105	17	108	16	112	12
90	7	93	11	96	11	98	12	99	10	100	12	102	15	103	11	104	15	105	13	108	14	112	16
90	9	94	8	96	10	98	7	99	11	100	14	102	16	103	14	104	13	106	16	108	14	113	15
90	4	94	6	97	12	98	16	99	8	101	17	102	13	103	14	104	14	106	16	108	12	113	21
91	6	94	9	97	6	98	8	99	11	101	13	102	10	103	13	104	17	106	14	109	15	114	14
91	6	94	5	97	8	98	11	99	12	101	13	102	12	103	16	105	15	106	7	109	13	116	16
92	8	94	9	97	8	98	5	99	11	101	6	102	13	103	15	105	12	107	12	109	10		

Table 2.12a. Northeast Atlantic spurdog. C_{SQ} assessment. Estimates of key model parameters, with associated Hessian-based estimates of precision (CV expressed as a percentage) for the base-case run, and two sensitivity tests for alternative values of Q_{fec}.

	Q_{fec} = 2.149 base case		Q_{fec} = 2.629		Q_{fec} = 3.792	
$N_0^{f,preg}$	93417	2.1%	80511	2.0%	61433	2.1%
Q_{fec}	2.149	2.2%	2.630	2.7%	3.793	3.5%
q_{sur}	0.00050462	21%	0.00049215	21%	0.00042988	16%
B_{depl05}	0.274	23%	0.364	24%	0.668	17%
B_{depl55}	0.334	23%	0.431	23%	0.725	16%

Table 2.12b. Northeast Atlantic spurdog. C_{SQ} assessment. Estimates of other estimates of interest for the base case run, and two sensitivity tests for alternative values for Q_{fec}. MSY $B_{trigger}$ is calculated as $B_{MSY}/1.4$.

	Q_{fec} = 2.149 base case	Q_{fec} = 2.629	Q_{fec} = 3.792
M_{pup}	0.730	0.638	0.480
a_{fec}	-11.915	-9.620	-7.007
b_{fec}	0.175	0.143	0.106
$F_{prop,msy}$	0.0333	0.0416	0.0578
MSY	22847	27167	34056
B_{MSY}	947895	864684	749088
MSY $B_{trigger}$	677068	617631	535063
MSYR	0.0337	0.0456	0.0705
$-\ln L_{tot}$	2150.14	2148.25	2150.16

Table 2.13. Northeast Atlantic spurdog. C_{SQ} assessment. Correlation matrix for some key estimable parameters for the base-case. Correlations with absolute values greater than 0.5 are shaded.

	$N_0^{f,preg}$	$S_{c2,non-tgt}$	$S_{c2,tgt}$	$S_{c3,non-tgt}$	$S_{c3,tgt}$	$S_{c4,non-tgt}$	$S_{c4,tgt}$	S_{s1}	S_{s2}	S_{s3}	S_{s4}	Q_{fec}	$\varepsilon_{r,11}$	$\varepsilon_{r,12}$	$\varepsilon_{r,13}$	$\varepsilon_{r,14}$	$\varepsilon_{r,15}$	q_{sur}
$N_0^{f,preg}$	1																	
$S_{c2,non-tgt}$	-0.11	1																
$S_{c2,tgt}$	-0.01	0.00	1															
$S_{c3,non-tgt}$	-0.23	0.41	0.01	1														
$S_{c3,tgt}$	-0.05	0.01	0.08	0.05	1													
$S_{c4,non-tgt}$	-0.30	0.43	0.01	0.88	0.07	1												
$S_{c4,tgt}$	-0.19	0.06	0.10	0.16	0.53	0.19	1											
S_{s1}	0.04	-0.04	-0.01	-0.09	-0.06	-0.10	-0.10	1										
S_{s2}	0.07	-0.05	-0.01	-0.11	-0.07	-0.13	-0.12	0.45	1									
S_{s3}	0.07	-0.04	-0.01	-0.08	-0.04	-0.09	-0.08	0.37	0.50	1								
S_{s4}	0.03	-0.03	-0.01	-0.08	-0.06	-0.08	-0.08	0.31	0.41	0.35	1							
Q_{fec}	0.03	0.05	0.01	0.17	0.17	0.17	0.22	-0.07	-0.05	0.01	-0.05	1						
$\varepsilon_{r,11}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.02	0.00	-0.01	1					
$\varepsilon_{r,12}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.03	-0.02	0.00	-0.01	-0.01	1				
$\varepsilon_{r,13}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.05	-0.01	0.00	-0.01	0.00	-0.01	1			
$\varepsilon_{r,14}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	-0.05	0.00	0.00	0.00	0.01	0.00	-0.01	1		
$\varepsilon_{r,15}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	-0.03	0.00	0.00	0.00	0.01	0.01	0.00	0.00	1	
q_{sur}	-0.31	0.02	0.00	-0.03	-0.13	-0.02	-0.12	-0.15	-0.26	-0.33	-0.33	-0.70	0.02	0.01	0.01	0.00	0.00	1

Table 2.14. Northeast Atlantic spurdog. C_{SQ} assessment. Summary table of estimates from the base case assessment: recruitment (thousands of pups), total biomass (t) and fishing proportion or harvest rate (with selectivity averaged over ages 5–30); and WG estimates of landings (t) used in the assessment. The final recruitment value is taken directly from the estimated stock-recruit relationship.

	R (thousand pups)	B_{tot} (t)	Catch (t)	F_{prop} (5–30)
1980	201978	610689	40968	0.0961
1981	186439	589858	39962	0.0968
1982	176741	569390	32402	0.0813
1983	175534	556001	37046	0.0951
1984	165603	536749	35194	0.0936
1985	155728	518118	38674	0.1057
1986	154396	495329	30910	0.0876
1987	151916	479593	42356	0.1237
1988	146326	451678	35569	0.1103
1989	149195	430545	30279	0.0986
1990	141481	414059	29906	0.1018
1991	150016	398381	29563	0.1051
1992	139977	382497	29046	0.1074
1993	125495	366360	25637	0.0999
1994	122513	353561	20851	0.0848
1995	110081	344800	21318	0.0878
1996	110676	335472	17295	0.0729
1997	111196	329881	15348	0.0654
1998	110517	325745	13919	0.0596
1999	108857	322461	12385	0.0534
2000	110300	320323	15891	0.0685
2001	109414	314278	16693	0.0734
2002	111693	307387	11170	0.0504
2003	117282	306239	12247	0.0554
2004	119778	304086	9366	0.0428
2005	122471	304972	8426	0.0388
2006	121151	306748	4109	0.0187
2007	126186	313169	2929	0.0131
2008	132629	321145	1836	0.0079
2009	140680	330671	2640	0.0111
2010	156007	340320	2468	0.0101
2011	139083	349172	2468	0.0099
2012	139111	358102	2468	0.0097
2013	144843	367455	2468	0.0094
2014	143472	376770	2468	0.0091
2015	148238	386343	2468	0.0089
2016	158787	396400	2468	0.0087

	R (thousand pups)	B_{tot} (t)	Catch (t)	F_{prop} (5–30)
2017	162968	406569	2468	0.0084
2018	166211	416836	2468	0.0082
2019	158133	426532	2468	0.0080
2020	171756	436999		0.0961

Table 2.15a. Northeast Atlantic spurdog. C_{SQ} assessment. Assessment projections under different future catch options. Estimates of begin-year total biomass relative to the total biomass in 2020 are shown, assuming that the catch in 2020 is 2486 tons (average landings for 2007–2009). Point estimates are given in the upper third of the table with corresponding lower and upper values (reflecting ±2 standard deviations) given in the middle and bottom third of the table. All landings from 2008 onwards are assumed to be taken by non-target fisheries only. The "+x yrs" in the first column is relative to 2020 (so "+3 yrs" indicates 2023).

	Medium-term projections				
	MSY approach	zero	TAC 2009	Ave catch 2007–2009	MSY harvest rate
average catch*	10327	0	1422	2468	12011
Point estimates					
+ 3 yrs	1.05	1.09	1.08	1.08	1.04
+ 5 yrs	1.08	1.15	1.14	1.13	1.05
+ 10 yrs	1.16	1.32	1.29	1.27	1.09
+ 30 yrs	1.42	2.15	2.05	1.98	1.28
Point estimates -2 standard deviations					
+ 3 yrs	1.02	1.06	1.06	1.05	1.01
+ 5 yrs	1.03	1.11	1.10	1.09	1.01
+ 10 yrs	1.05	1.25	1.22	1.20	1.02
+ 30 yrs	1.11	1.86	1.81	1.76	1.10
Point estimates +2 standard deviations					
+ 3 yrs	1.08	1.11	1.10	1.10	1.06
+ 5 yrs	1.13	1.19	1.17	1.16	1.09
+ 10 yrs	1.26	1.40	1.36	1.34	1.17
+ 30 yrs	1.74	2.43	2.29	2.19	1.45

*** "average catch" is the average for the projection period 2021–2049**

Table 2.15b. Northeast Atlantic spurdog. C_{SQ} assessment. As for Table 2.15a, but this table shows estimates of begin-year total biomass relative to MSY $B_{trigger}$ (see Table 2.12b).

	Medium-term projections				
	MSY approach	**zero**	**TAC 2009**	**Ave catch 2007–2009**	**MSY harvest rate**
average catch*	10327	0	1422	2468	12011
Point estimates					
+ 3 yrs	0.68	0.70	0.70	0.69	0.67
+ 5 yrs	0.70	0.74	0.73	0.73	0.68
+ 10 yrs	0.75	0.85	0.84	0.82	0.71
+ 30 yrs	0.92	1.38	1.32	1.28	0.82
Point estimates -2 standard deviations					
+ 3 yrs	0.65	0.68	0.67	0.67	0.64
+ 5 yrs	0.65	0.71	0.70	0.69	0.64
+ 10 yrs	0.64	0.78	0.76	0.75	0.64
+ 30 yrs	0.60	1.10	1.08	1.06	0.65
Point estimates +2 standard deviations					
+ 3 yrs	0.71	0.72	0.72	0.72	0.69
+ 5 yrs	0.75	0.78	0.77	0.76	0.72
+ 10 yrs	0.85	0.93	0.91	0.89	0.78
+ 30 yrs	1.23	1.67	1.56	1.49	1.00

*** "average catch" is the average for the projection period 2021–2049**

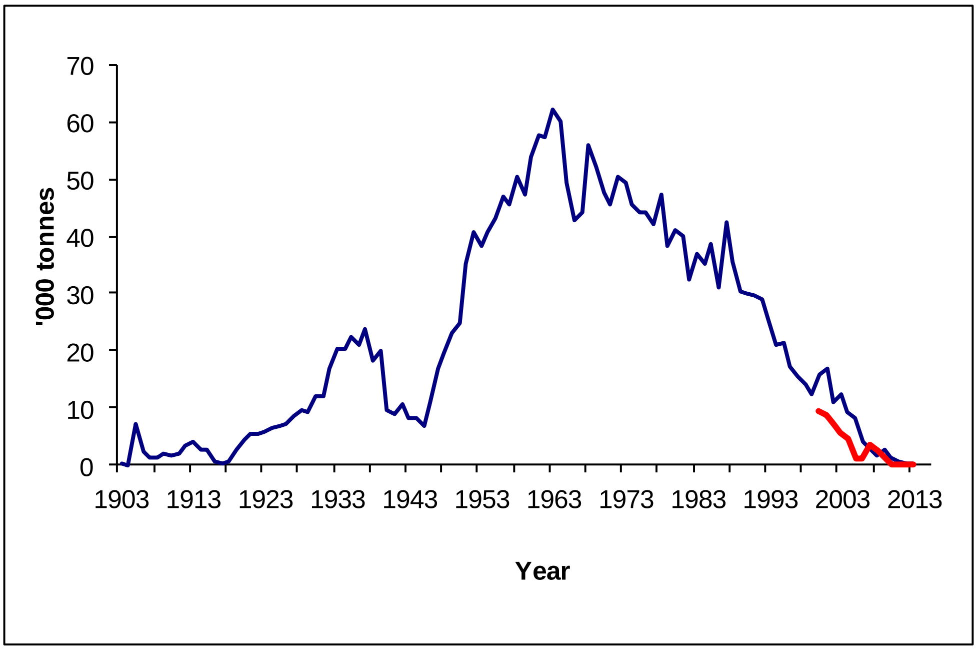


Figure 2.1. Northeast Atlantic spurdog. WG estimates of total international landings of NE Atlantic spurdog (1903–2013, blue line) and TAC (red line). Restrictive management (e.g. through quotas and other measures) is only thought to have occurred since 2007.

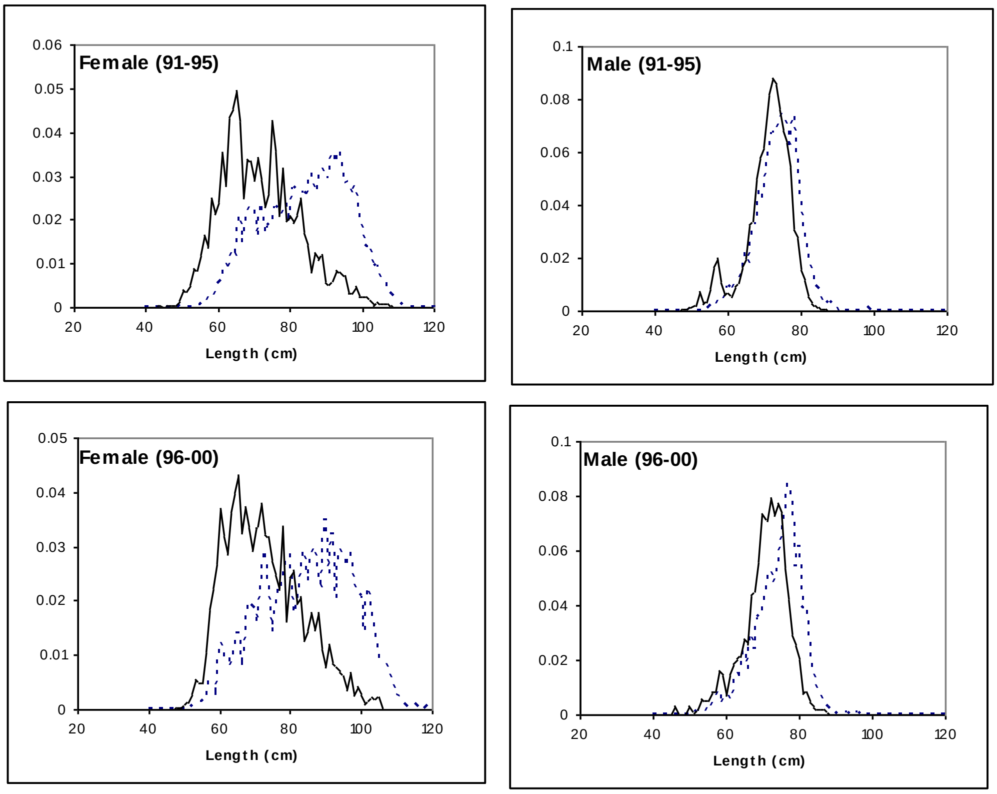


Figure 2.2. Northeast Atlantic spurdog. Comparison of length–frequency distributions (proportions) obtained from market sampling of Scottish (solid line) and UK (E&W) (dashed line) landings data. Data are sex-disaggregated, but averaged over five-year intervals.

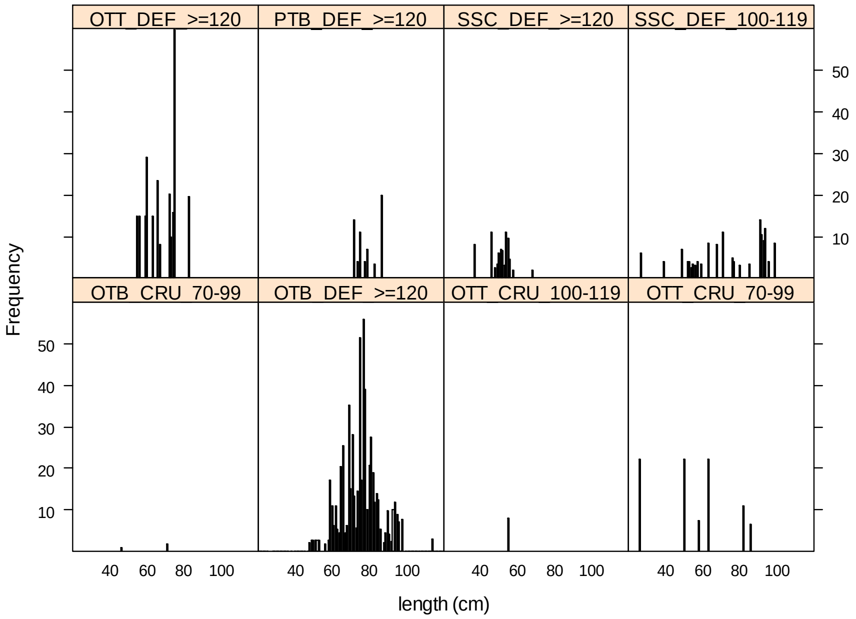


Figure 2.3. Northeast Atlantic spurdog. Length distributions of spurdog caught on Scottish observer trips in 2010. Data are aggregated across trips for each gear category. Gear codes relate to gear type, target species and mesh size. OTT – Otter trawl twin; PTB – Pair trawl bottom; SSC – Scottish Seine; OTB – Otter trawl bottom; DEF – demersal fish; CRU – crustacean.

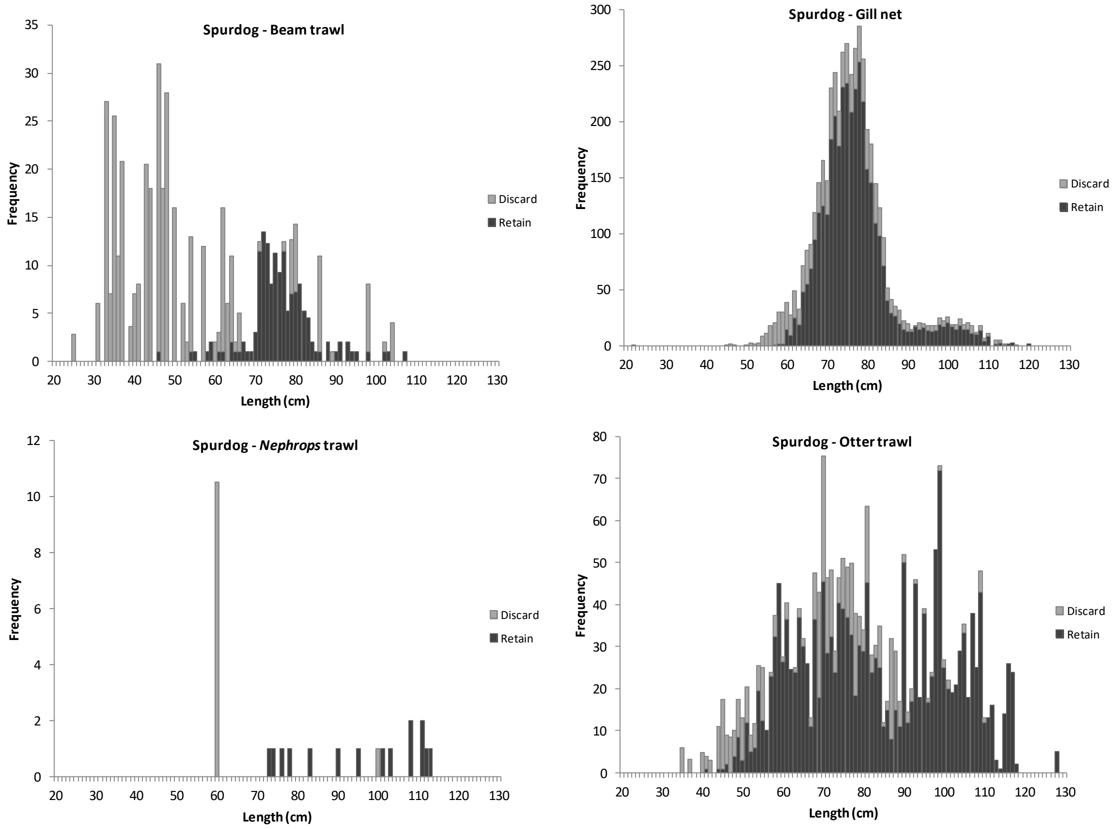


Figure 2.4. Northeast Atlantic spurdog. Discard-retention patterns of spurdog taken in UK (English) vessels using beam trawl, gillnet, *Nephrops* trawl and otter trawl.

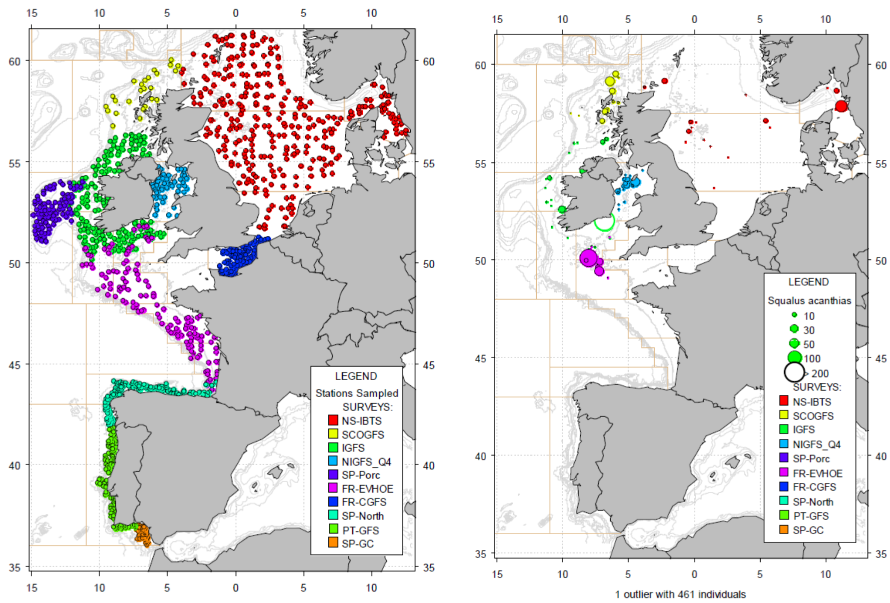


Figure 2.5. Northeast Atlantic spurdog. Overall spatial coverage of the IBTS (left) all surveys combined and (right) captures of spurdog (number per hour, bottom) as reported in the 2013 summer/autumn IBTS. The catchability of the different gears used in the NE Atlantic surveys is not constant; therefore, the map does not reflect proportional abundance in all the areas but within each survey (From ICES, 2014).

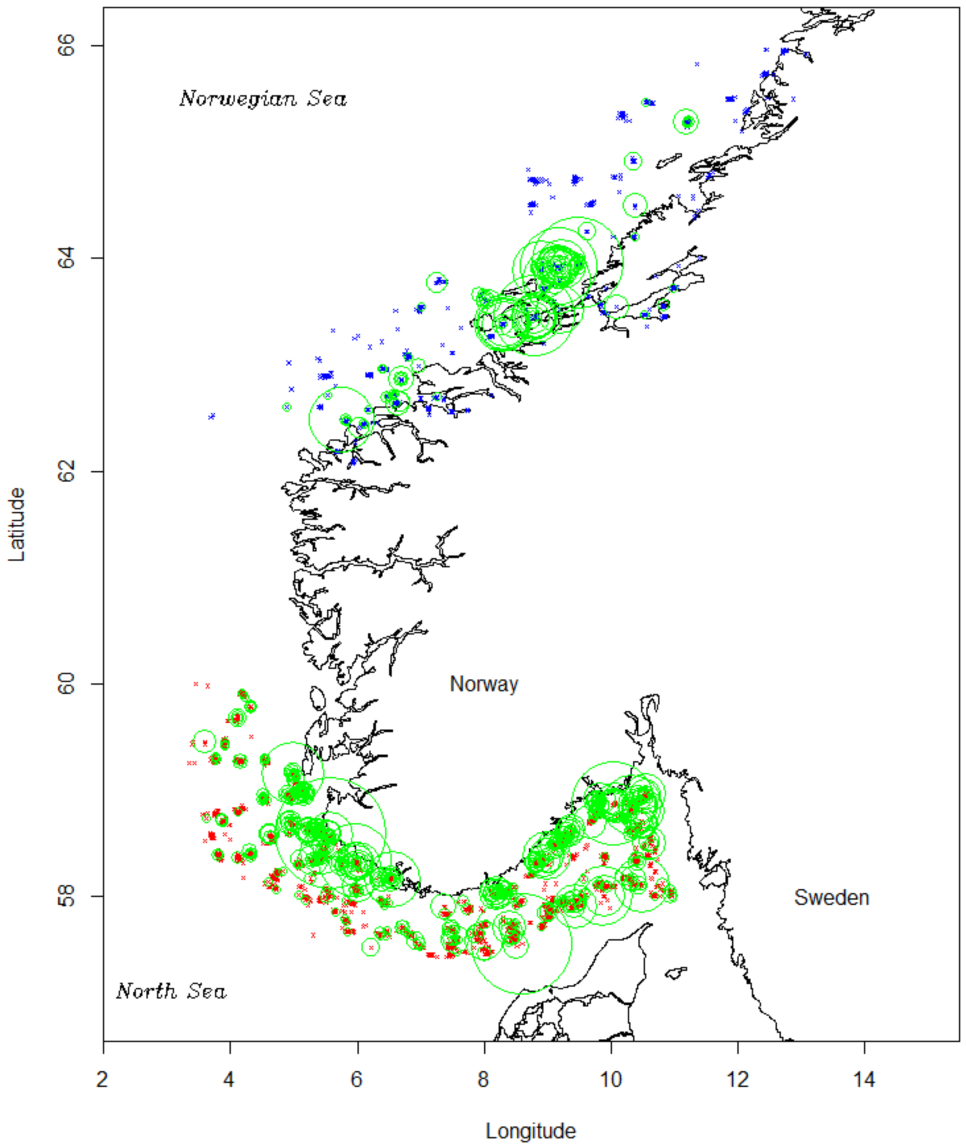


Figure 2.6. Northeast Atlantic spurdog. Map of survey areas with stations 1996–2017/18 for Coastal survey (blue) and Shrimp survey (red) for area 58–66°North. Green circles indicate catches of spurdog; circle area is proportional to catch in number of individuals. Source: Vollen (2014 WD), plus additional data from 2014 onwards.

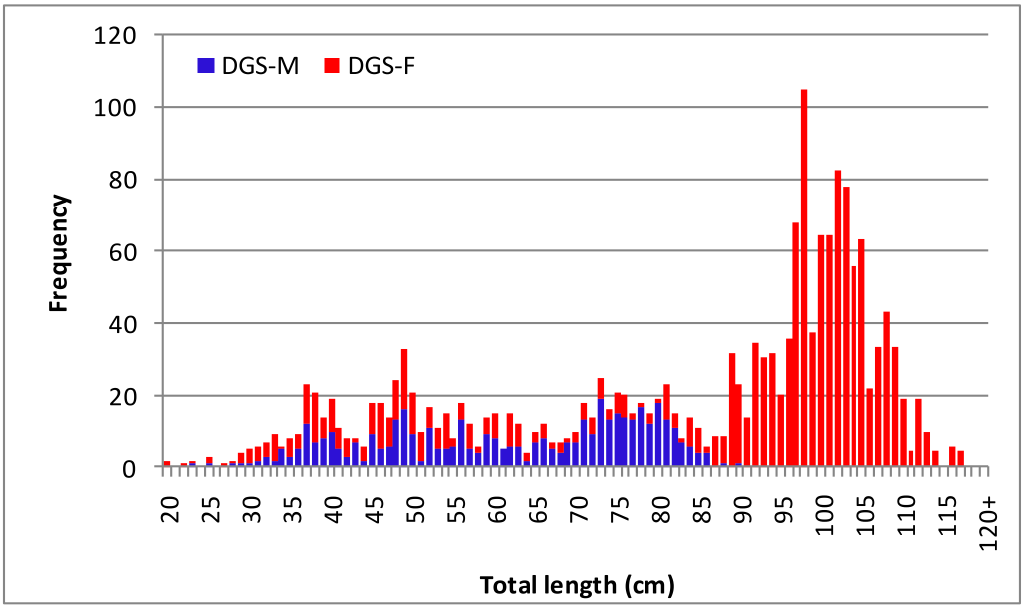


Figure 2.7a. Northeast Atlantic spurdog. Length distribution of spurdog captured in the UK (England and Wales) westerly IBTS in Q4 (2004–2009, all valid and additional tows). Length distribution highly influenced by a single haul of large females.

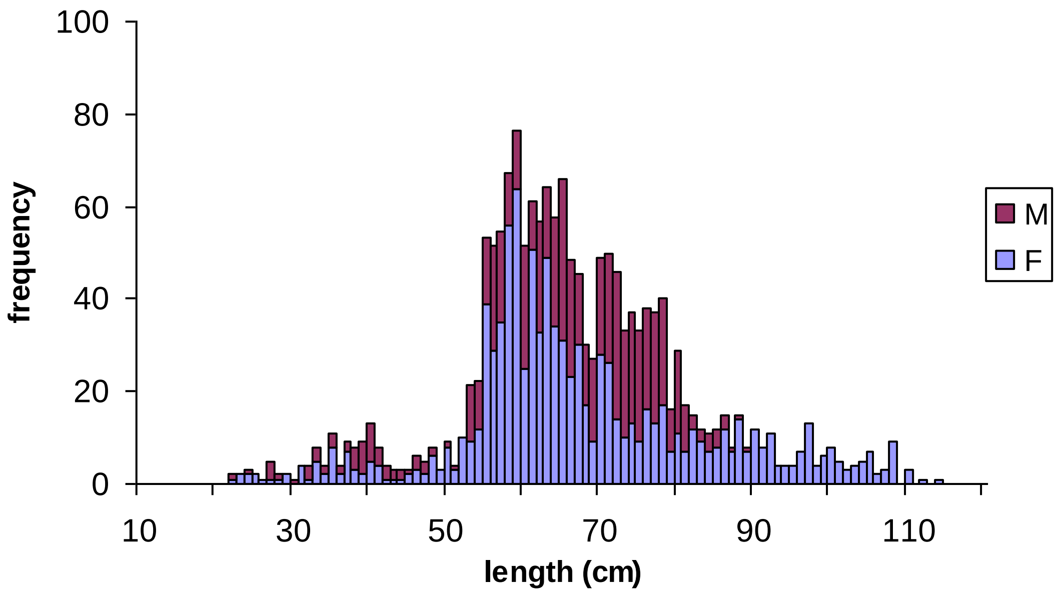


Figure 2.7b. Northeast Atlantic spurdog. Length distribution of spurdog captured in the Irish Q3 Celtic Seas groundfish survey (2003–2009).

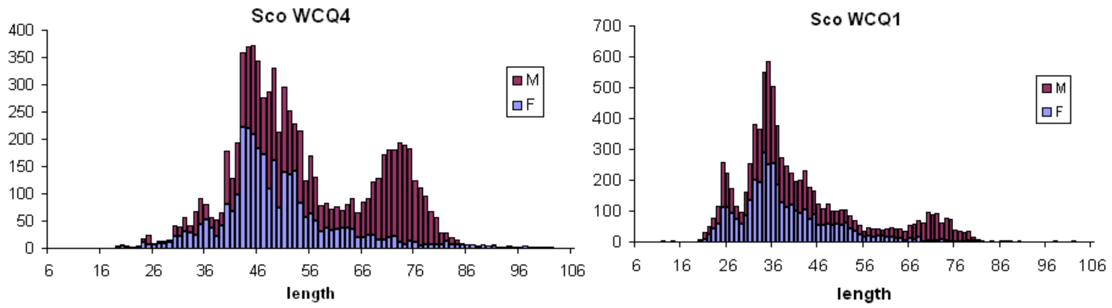


Figure 2.8. Northeast Atlantic spurdog. Length distribution of spurdog captured in the Scottish Q1 and Q4 groundfish surveys (1990–2010). Length–frequency distributions highly influenced by a small number of hauls containing many small individuals.

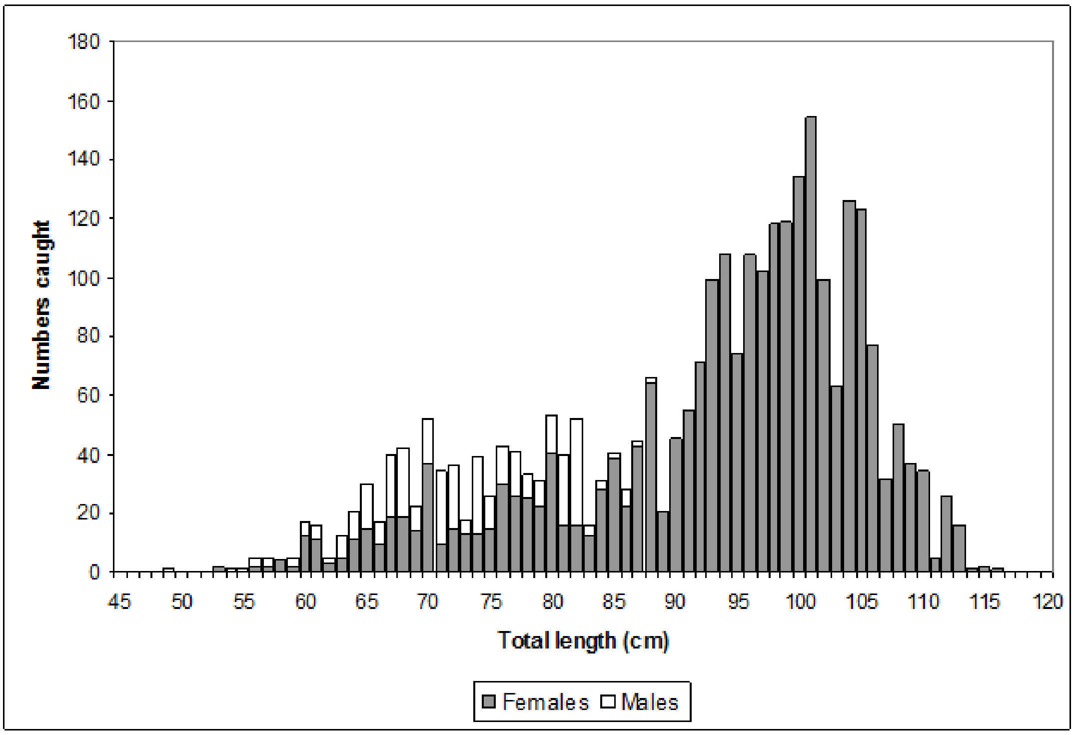


Figure 2.9. Northeast Atlantic spurdog. Total length–frequency of male and female spurdog taken during the UK(E&W) FSP survey, raised for those catches that were sub-sampled (n = 2517 females and 356 males).

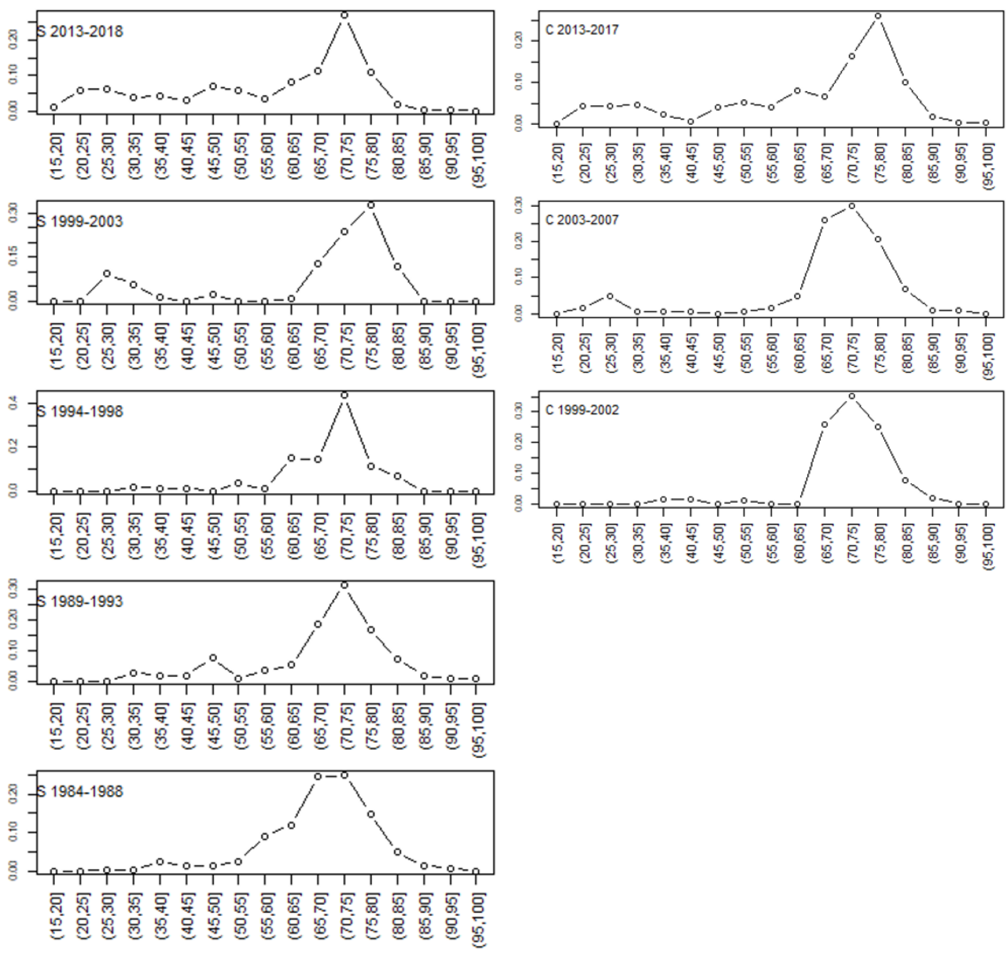


Figure 2.10. Northeast Atlantic spurdog. Relative length–frequency distributions (5 cm length groups and five-year periods) for the Shrimp survey 1985–2018 (left) and Coastal survey 1999–2017 (right).

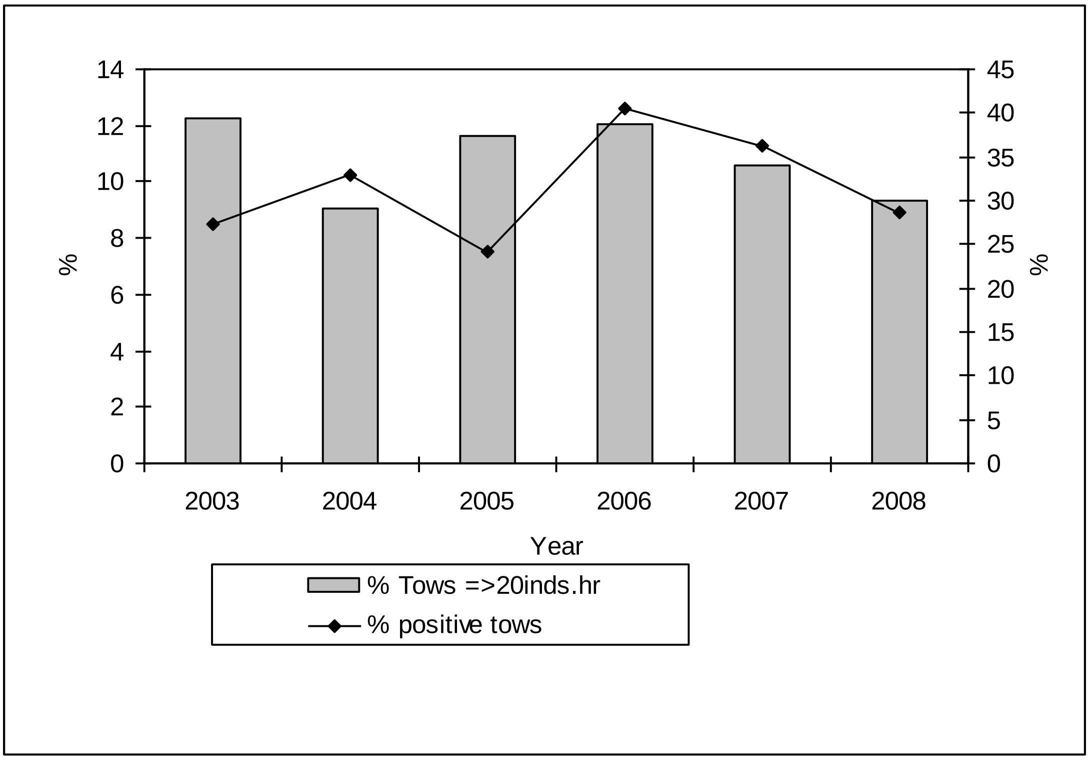


Figure 2.12. Northeast Atlantic spurdog. Proportion of survey hauls in Irish Q3 groundfish survey 2003–2008, ICES Area 7, in which nominal CPUE was ≥ 20 per one hour tow, and percentage of tows in which spurdog occurred.

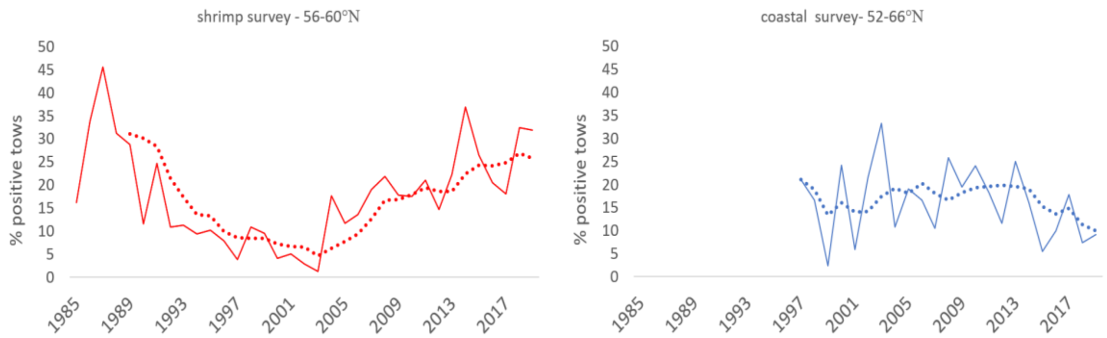


Figure 2.13. Northeast Atlantic spurdog. Percentage of tows in shrimp (left) and coastal (right) survey in which spurdog occurred by year, with moving average (dotted, 5 yrs).

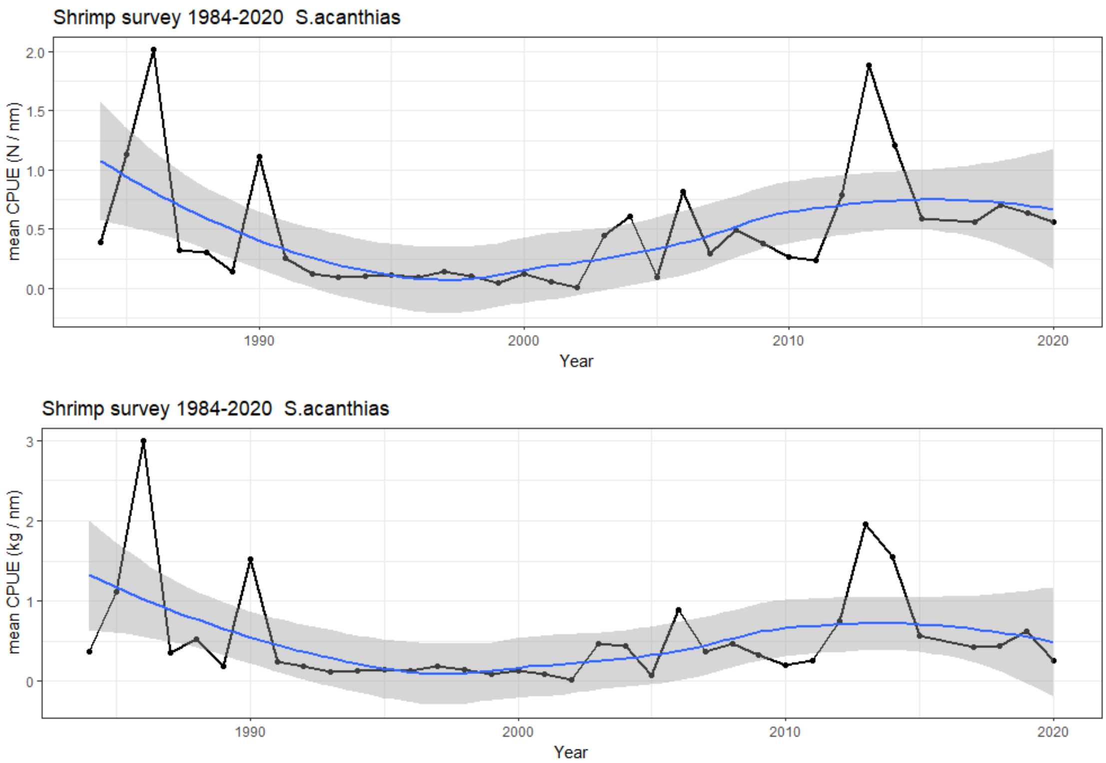


Figure 2.14. Northeast Atlantic spurdog. Mean CPUE for numbers per nm (top) and biomass per nm (bottom) by year with smooth for shrimp survey 1984–2020 (Junge *et al*. (2020 WD)).

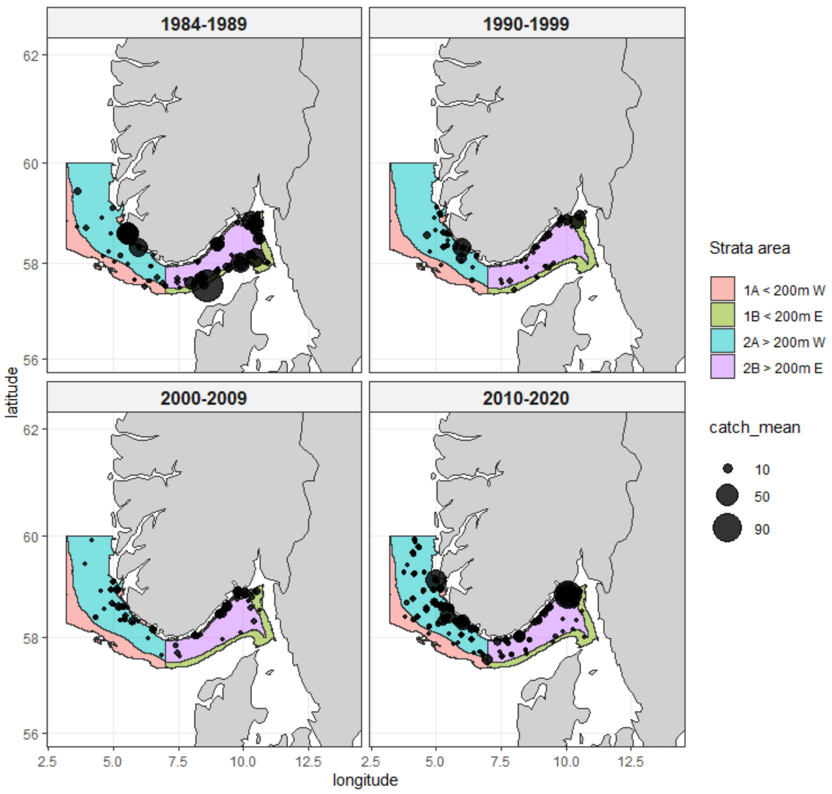
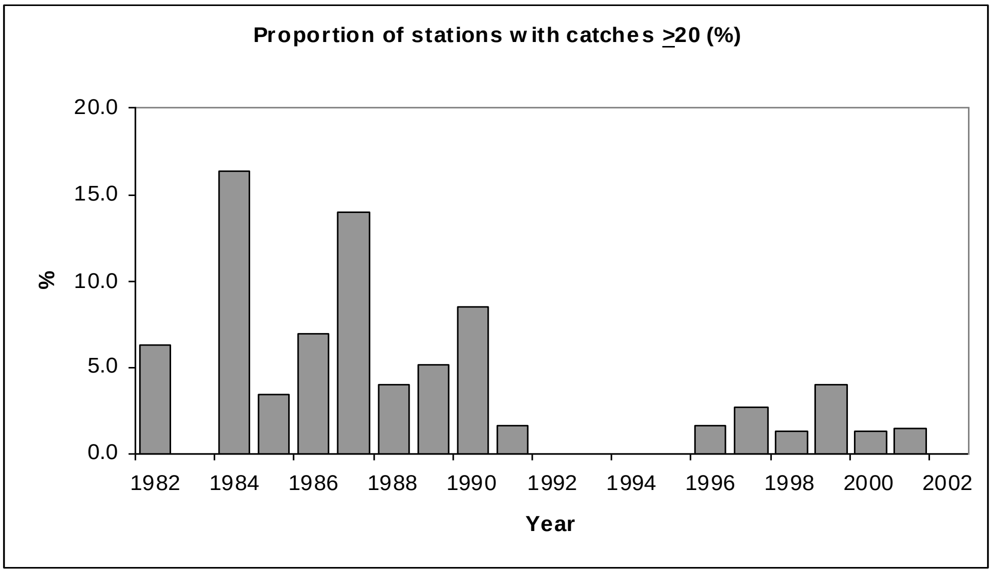


Figure 2.15. Northeast Atlantic spurdog. Mean catch numbers per strata by decade for shrimp survey 1984–2020 (Junge *et al*. (2020 WD)).



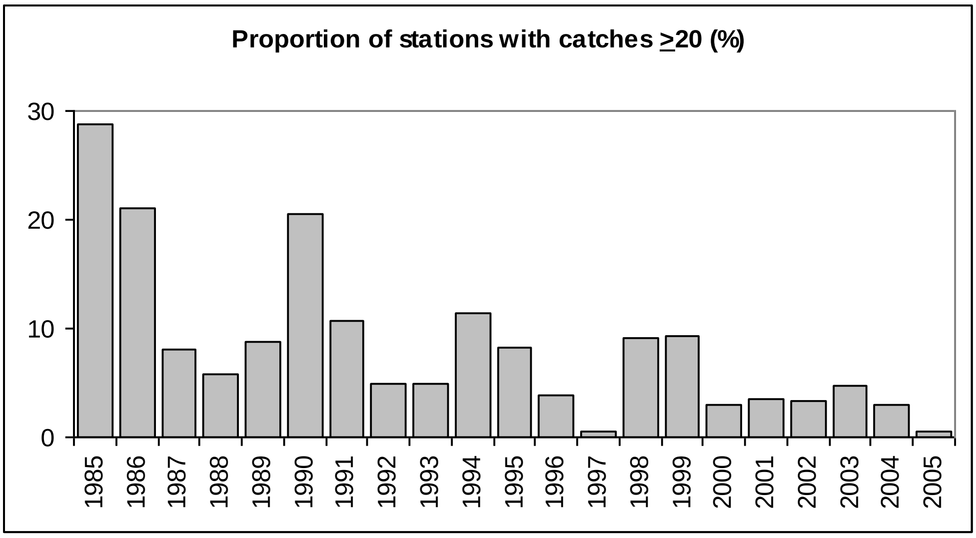
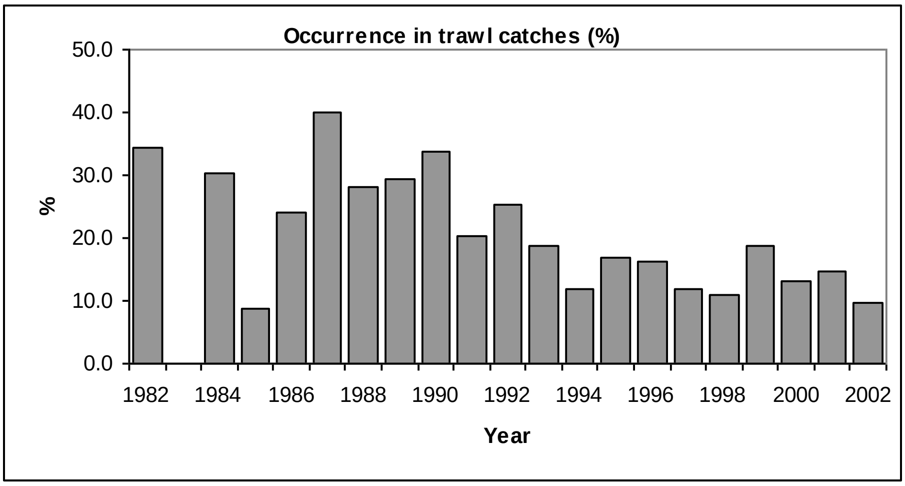


Figure 2.16. Northeast Atlantic spurdog. Proportion of survey hauls in the English Celtic Sea groundfish survey (1982–2002, top) and Scottish west coast (6.a) survey (Q1, 1985–2005, bottom) in which CPUE was ≥ 20 ind. h^{-1}. (Source: ICES, 2006).

a)



b)

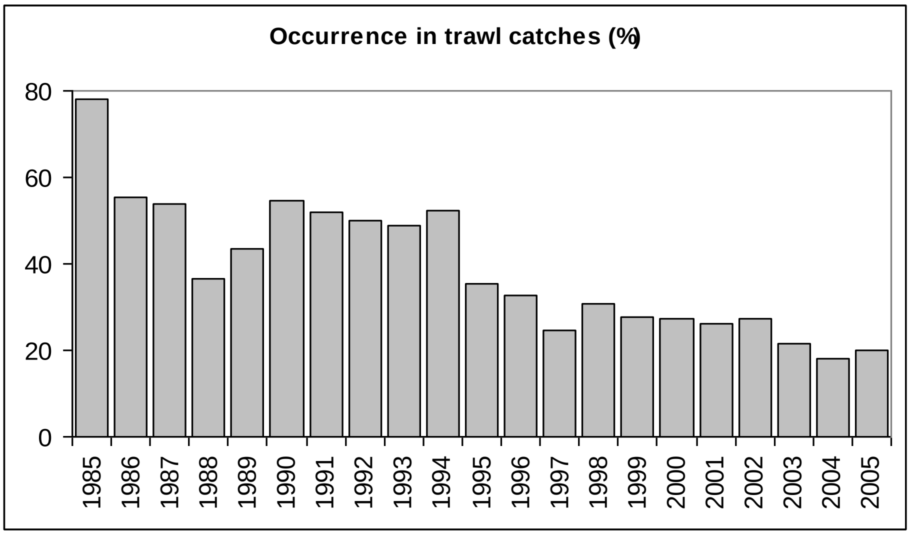


Figure 2.17. Northeast Atlantic spurdog. Frequency of occurrence in survey hauls in a) the English Q1 Celtic Sea groundfish survey (1982–2002), and b) the Scottish west coast (6.a) survey (Q1, 1985–2005).

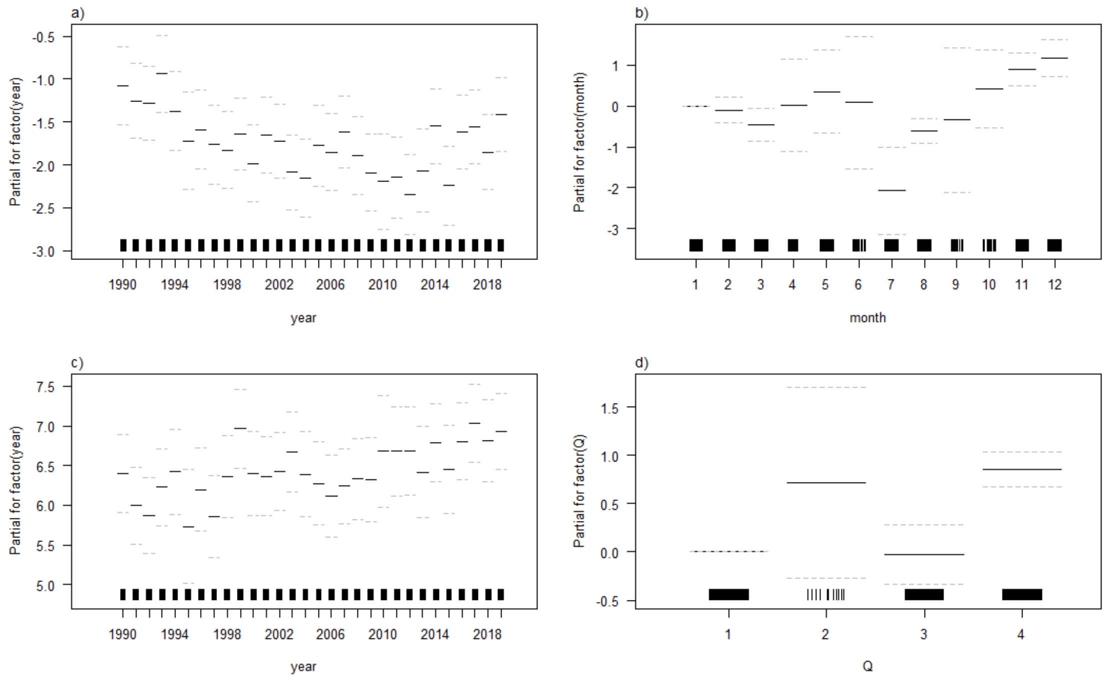


Figure 2.18. Northeast Atlantic spurdog. Estimated year and quarter effects (± 1 s.e.) from the delta-lognormal GLM: binomial model shown in a) and b), and lognormal results in c) and d) (log scale).

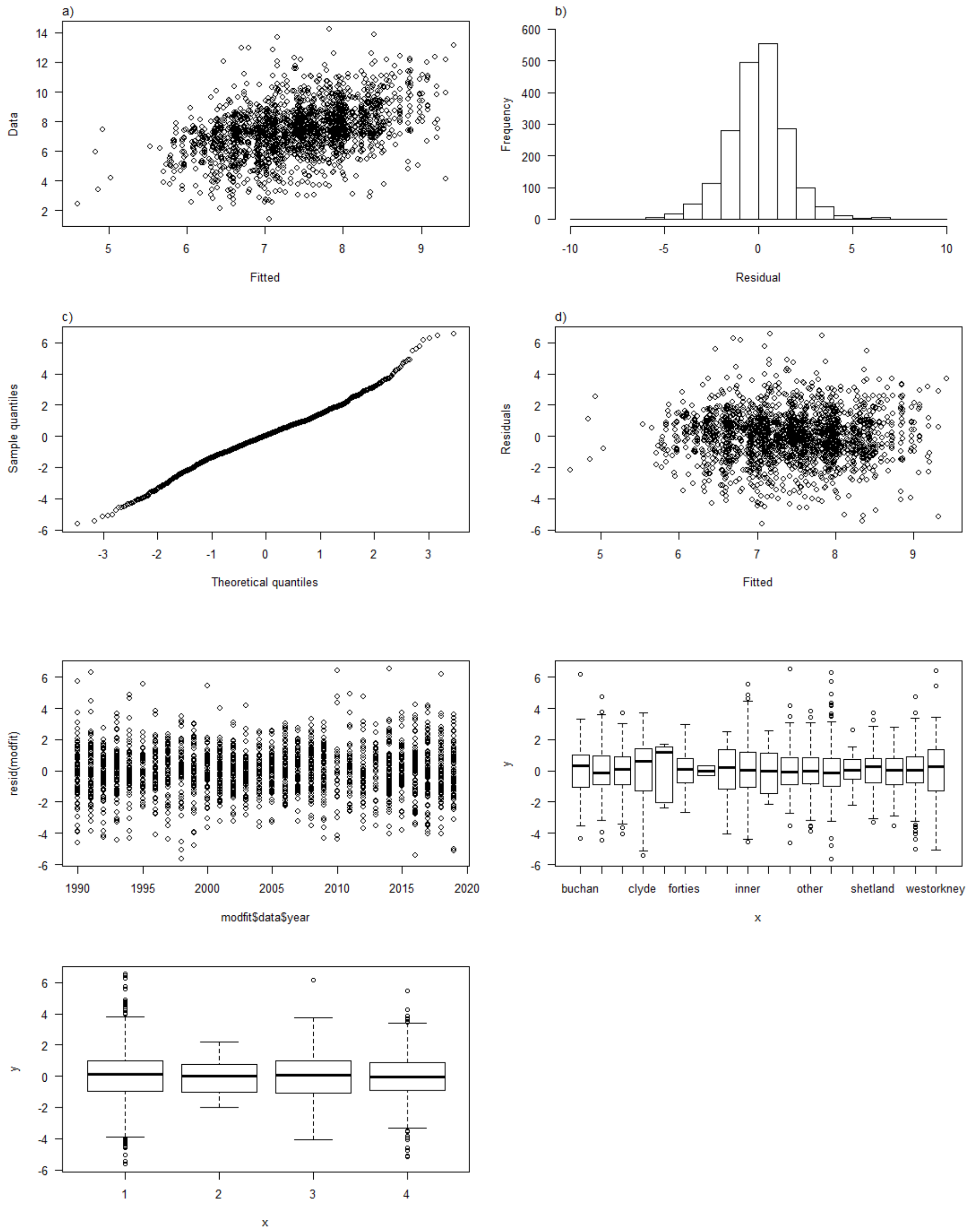


Figure 2.19. Northeast Atlantic spurdog. Analysis of Scottish survey data. Residual plot of final lognormal model fit: a) observed vs. fitted values, b) histogram of residuals, c) normal Q-Q plot, d) residuals vs. fitted values and e), f) and g) residuals vs. year, area and quarter.

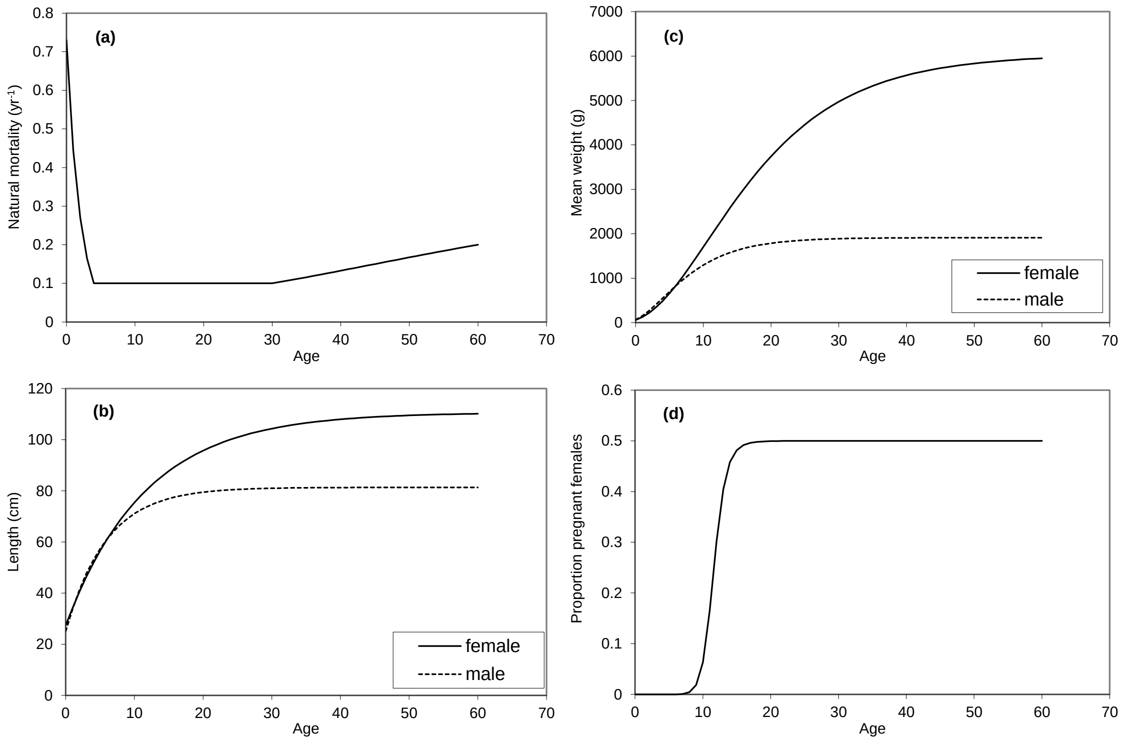


Figure 2.20. Northeast Atlantic spurdog. A visual representation of the life-history parameters described in Table 2.6. [Note, the value of natural mortality-at-age 0 is a parameter derived from the assessment.]

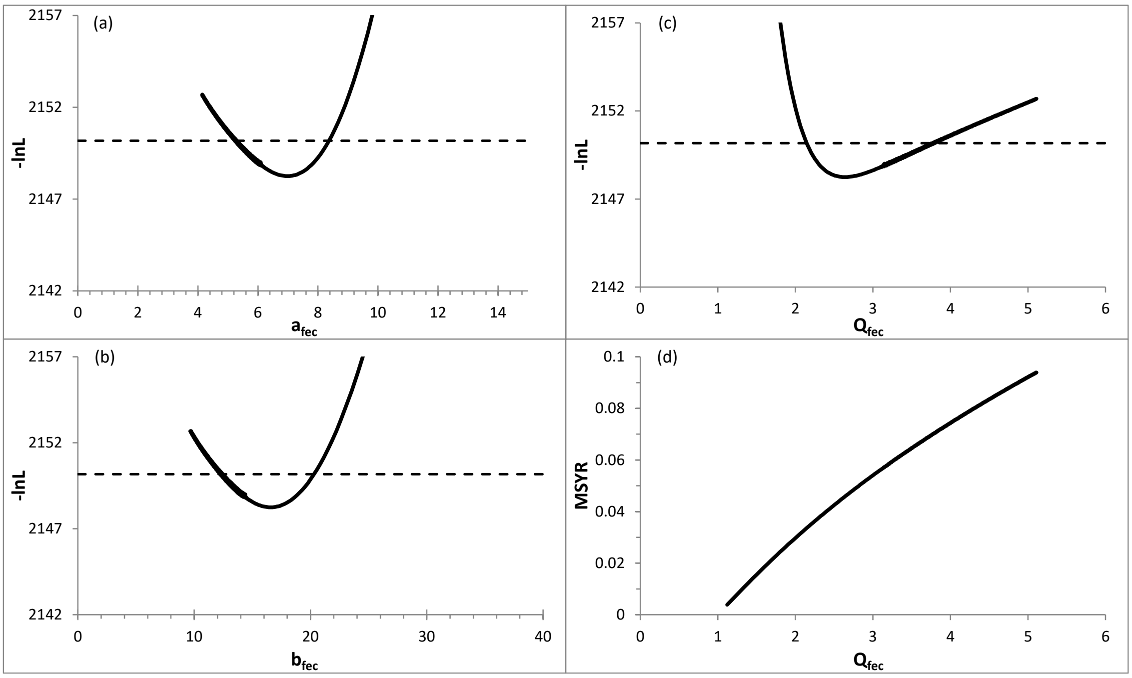


Figure 2.21. Northeast Atlantic spurdog. C_{SQ} assessment. Negative log-likelihood (-ln*L*) for a range of (a) a_{fec} and (b) b_{fec} values, with (c) corresponding Q_{fec}. Plot (d) shows MSYR (MSY/B_{MSY}) vs. Q_{fec}. Using the likelihood ratio criterion, the hashed line in plots (a)–(c) indicate the minimum –ln*L* value + 1.92, corresponding to 95% probability intervals for the corresponding parameters for values below the line.

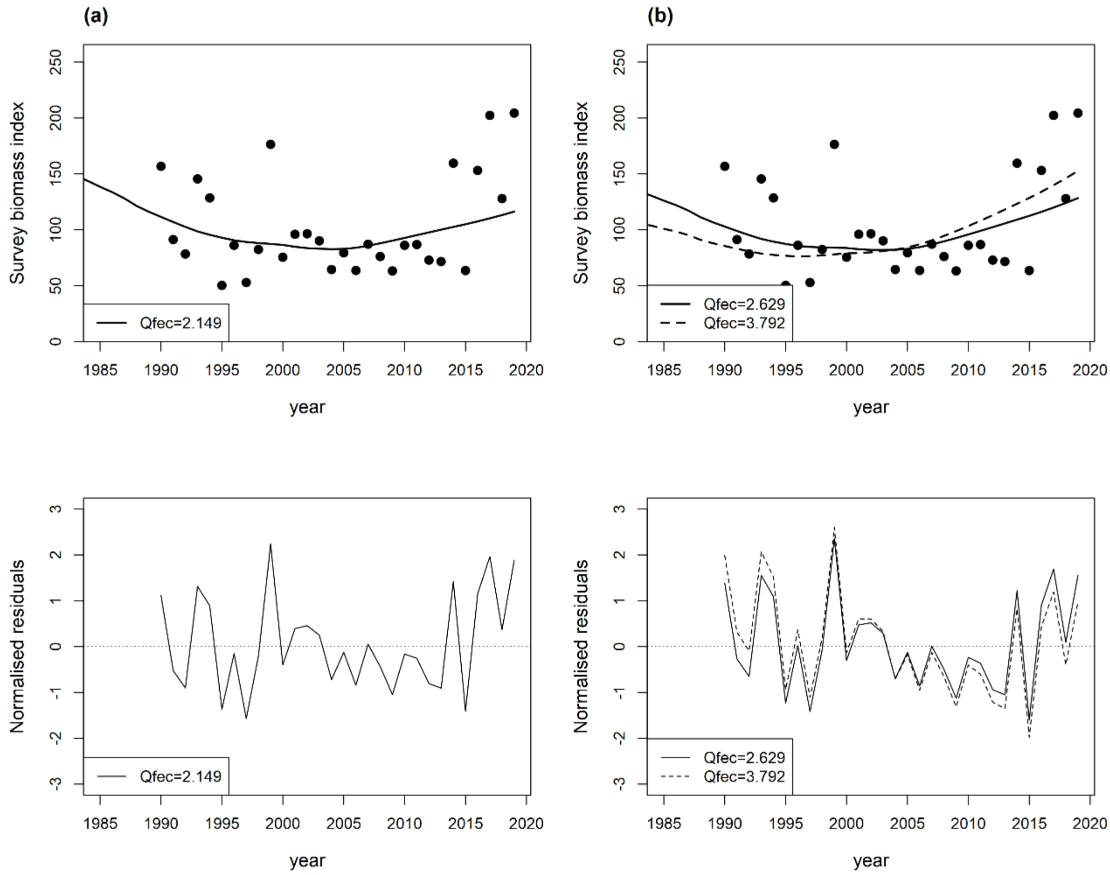


Figure 2.22. Northeast Atlantic spurdog. C_{SQ} assessment. Model fits to the Scottish surveys abundance index (top panel), with normalised residuals ($\varepsilon_{sur,y}$ in Stock Annex equation 9b) (bottom) for (a) the base-case Qfec = 2.000 (the more conservative lower bound in Figure 2.21c) and (b) for two alternatives (the optimum and upper bounds in Figure 2.21c) that fall within the 95% confidence bounds.

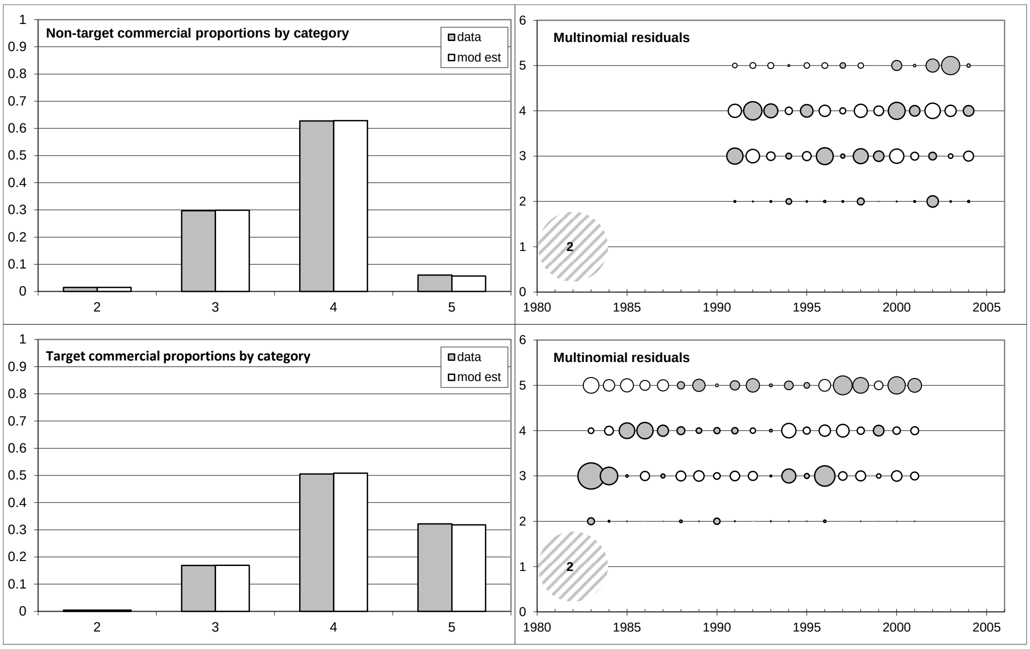


Figure 2.23a. Northeast Atlantic spurdog. C_{SQ} assessment. Model fits to the non-target (Scottish; top row) and target (England & Wales; bottom row) commercial proportions-by-length category data for the base case run. The left-hand side plots show proportions by length category averaged over the time period for which data are available, with the length category given along the horizontal axis. The right-hand side plots show multinomial residuals ($\varepsilon_{pcom,j,y,L}$ in Stock Annex equation 10b), with grey bubbles indicating positive residuals, bubble area being proportional to the size of the residual (the light-grey hashed bubble indicates a residual size of 2, and is shown for reference), and length category indicated on the vertical axis. The length categories considered are 2: 16–54 cm; 3: 55–69 cm; 4: 70–84 cm; 5: 85+ cm.

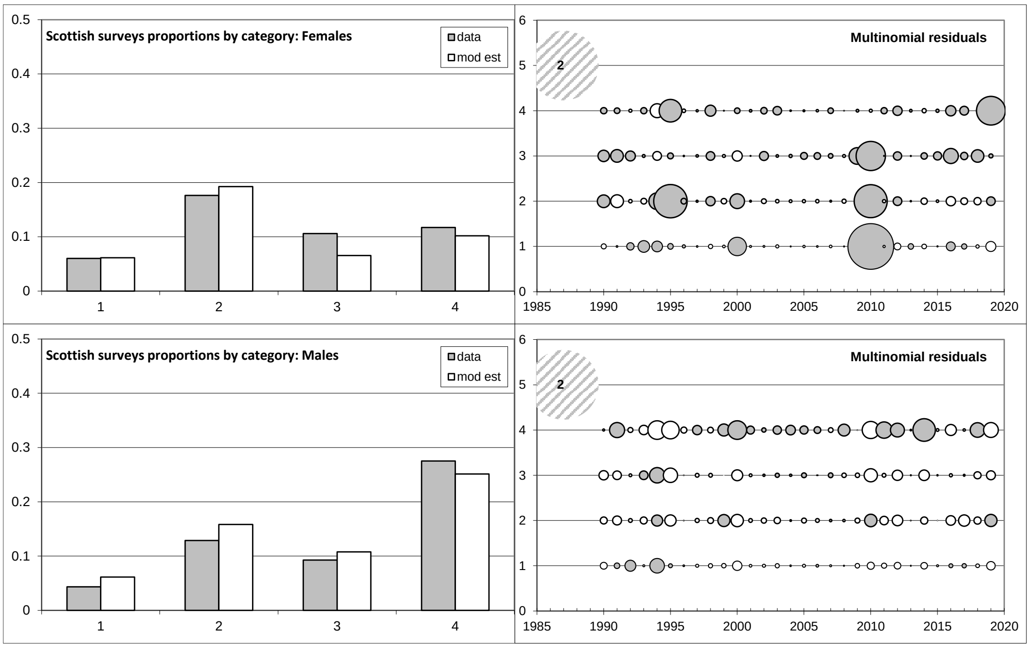


Figure 2.23b. Northeast Atlantic spurdog. C_{SQ} assessment. Model fits to the Scottish survey proportions-by-length category data for the base-case run for females (top row) and males (bottom row). A further description of these plots can be found in the caption to Figure 2.23a. Length categories considered are 1: 16–31 cm; 2: 32–54 cm; 3: 55–69 cm; 4: 70+ cm.

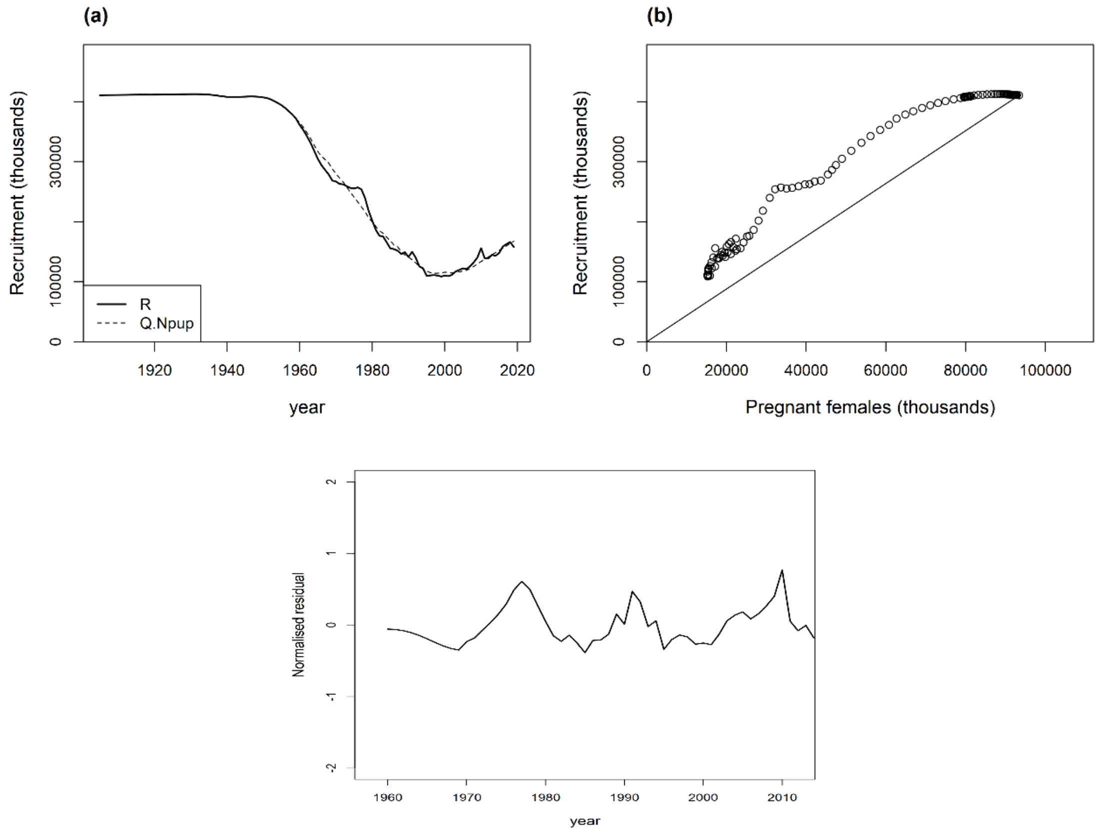


Figure 2.24. Northeast Atlantic spurdog. C_{SQ} assessment. (a) A comparison of the deterministic (N_{pup}) and stochastic (R) versions of recruitment (Stock Annex equations 2a–c) (top-left panel) with normalised residuals ($\varepsilon_{r,y}/\varepsilon_r$, where $\varepsilon_{r,y}$ are estimable parameters of the model) (bottom); and (b) a plot of recruitment (R) vs. number of pregnant females (in thousands; open circles), together with the replacement line (number of recruiting pups needed to replace the pregnant female population under no harvesting).

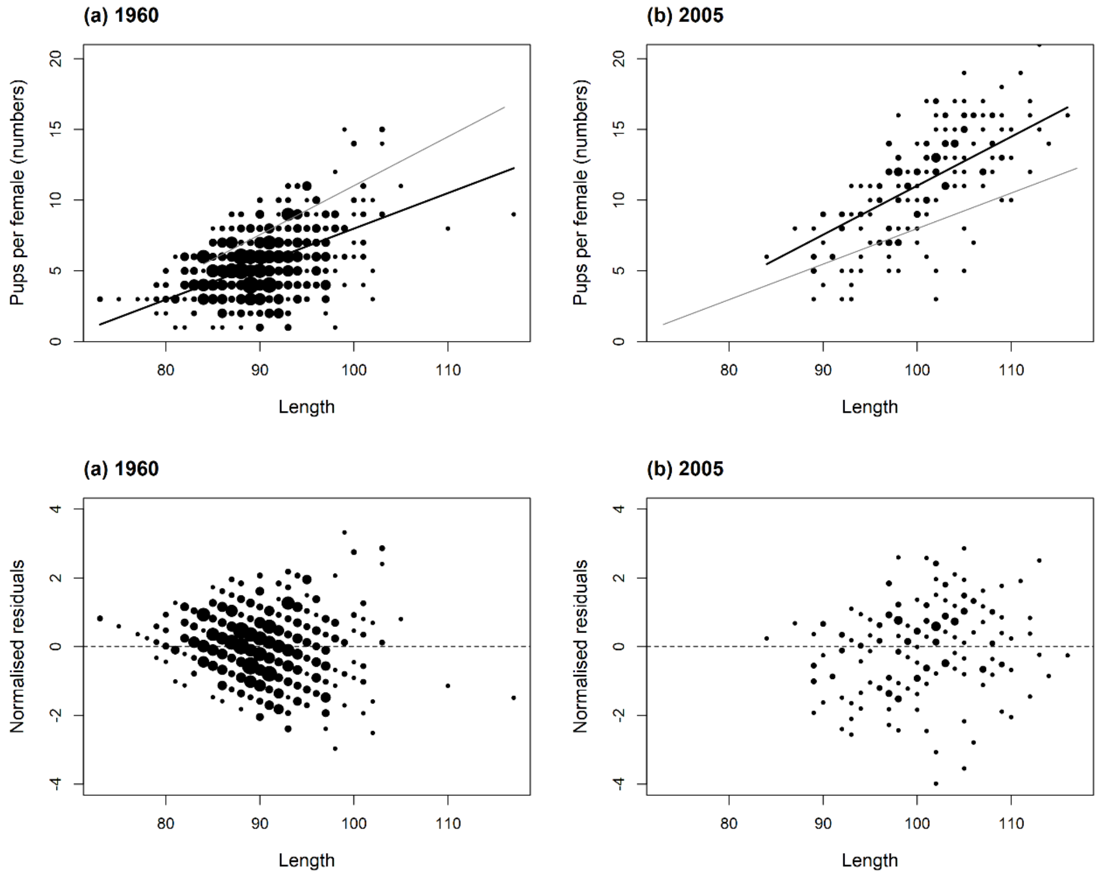


Figure 2.25. Northeast Atlantic spurdog. C_{SQ} assessment. Fit to fecundity data from two periods (top row) (a) 1960 and (b) 2005, with associated normalised residuals ($\varepsilon_{fec,k,y}$ in Stock Annex equation 11b) (bottom row). For the top plots, the heavy black lines reflect the model estimates for the given points, while the light grey ones, reflecting the model estimates for the points in the adjacent plot, are given for comparison. For all plots, the diameter of each point is proportional to $\sqrt{n}$, where *n* is the number of samples with the same number of pups for a given length.

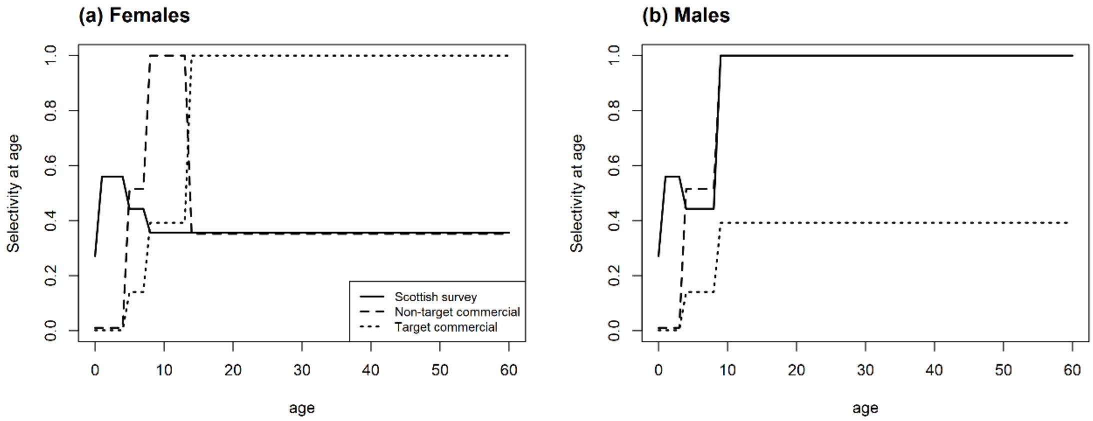


Figure 2.26. Northeast Atlantic spurdog. C_{SQ} assessment. Estimated selectivity-at-age curves for the base case run for (a) females and (b) males. The two commercial fleets considered have non-target (Scottish) and target (England & Wales) selectivity, which differ by sex because of the life-history parameters for males and females (Table 2.6). The survey selectivity relies on Scottish survey data.

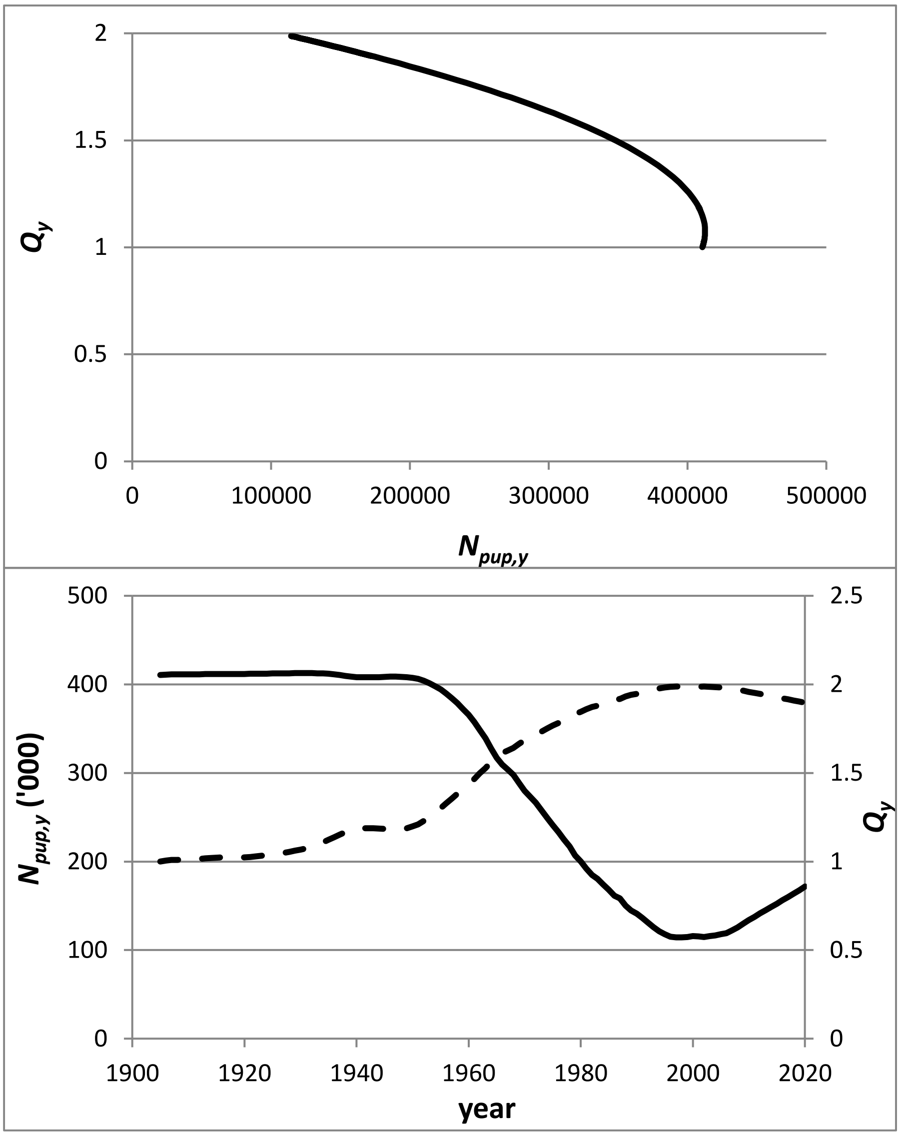


Figure 2.27. Northeast Atlantic spurdog. C_{SQ} assessment. A plot of the density-dependent factor Q_y (Stock Annex equation 2b) against the number of pups $N_{pup,y}$ (top; in thousands), and both plotted against time (bottom; solid line for $N_{pup,y}$, and hashed line for Q_y).

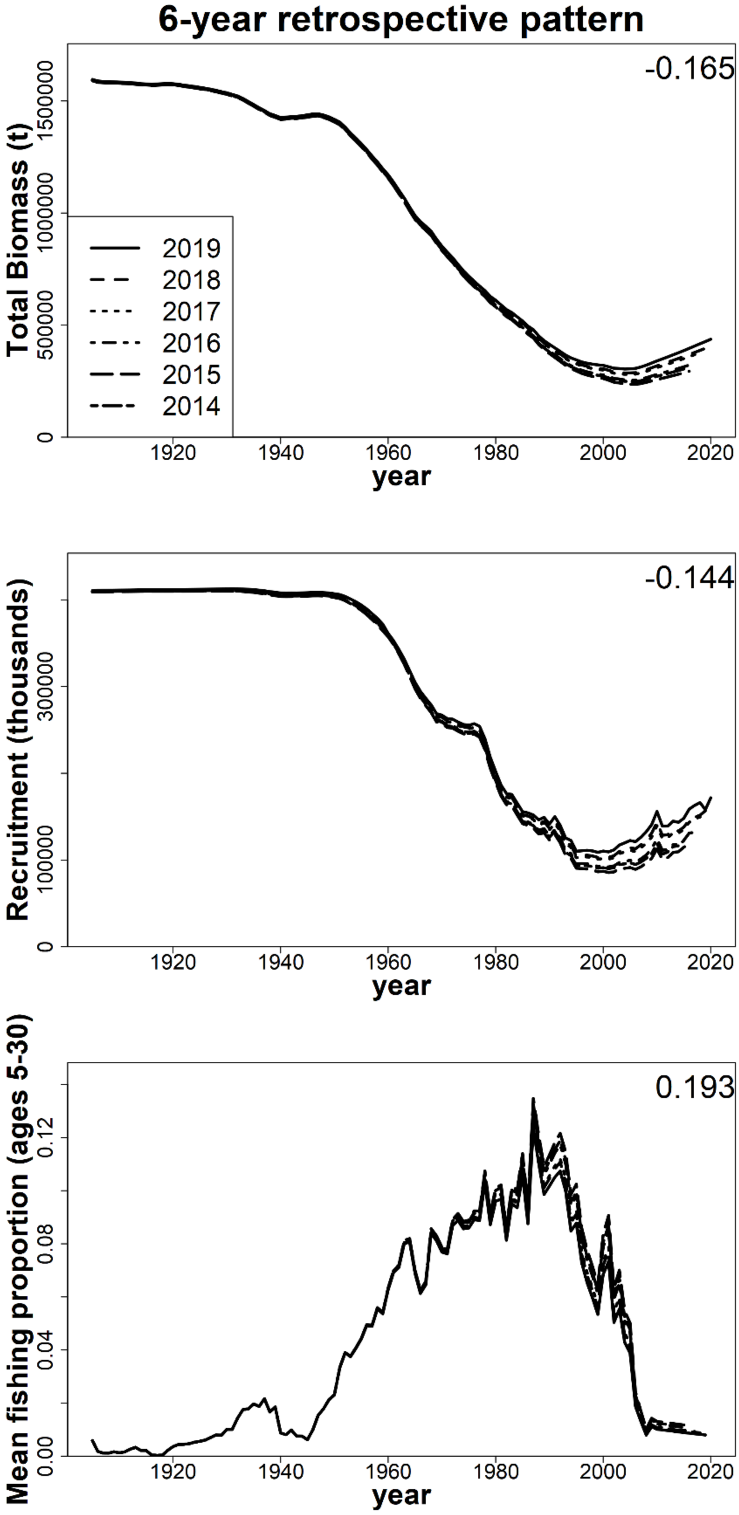


Figure 2.28. Northeast Atlantic spurdog. C_{SQ} assessment. Six-year retrospective plots (omitting probability intervals for clarity; the model was re-run, each time omitting a further year in the data). Mohn's rho is given in the top-right of each plot.

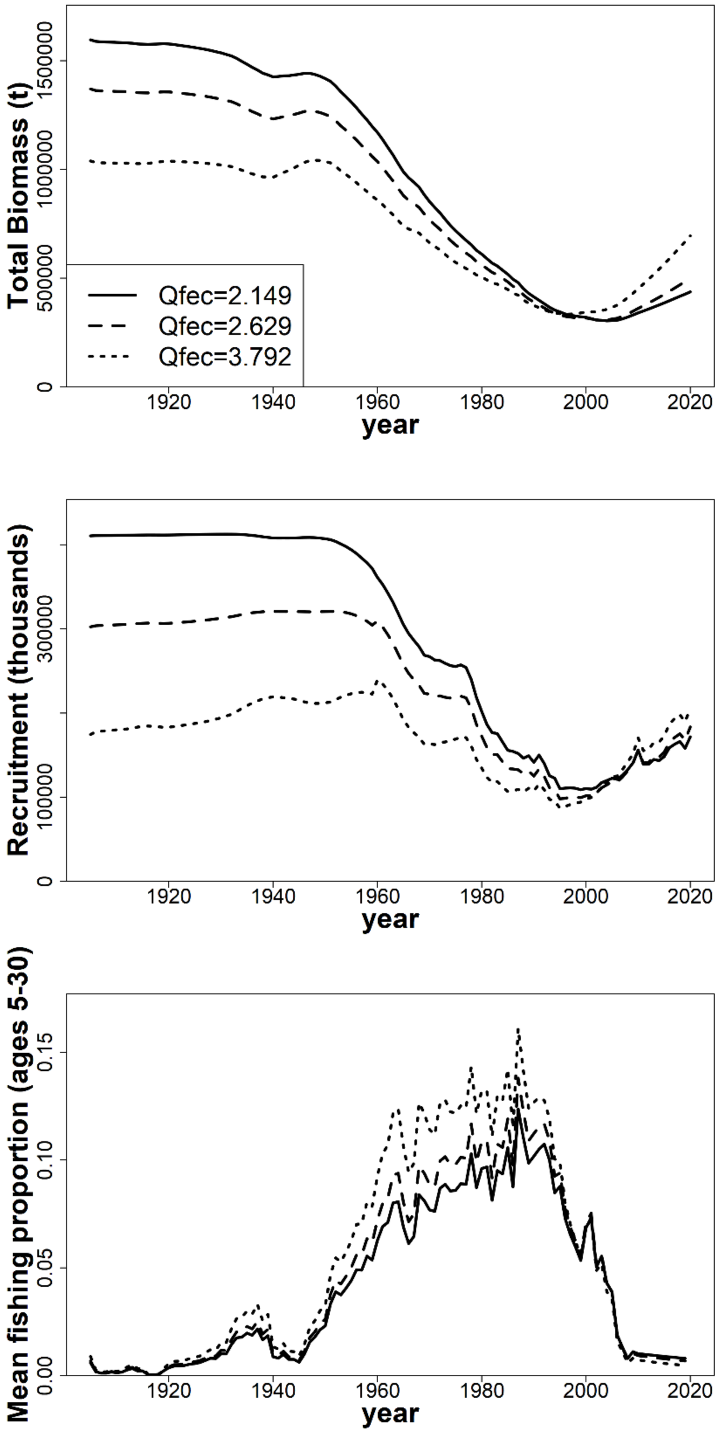


Figure 2.29. Northeast Atlantic spurdog. C_{SQ} assessment. A sensitivity analysis of the parameter that determines the extent of density-dependence in pup production (Q_{fec}). Three alternative values are considered, related to the smallest, optimum (in terms of lowest –ln*L*) and largest value of Q_{fec} below the hashed line in Figure 2.21c (respectively 2.149 [base case], 2.629 and 3.792).

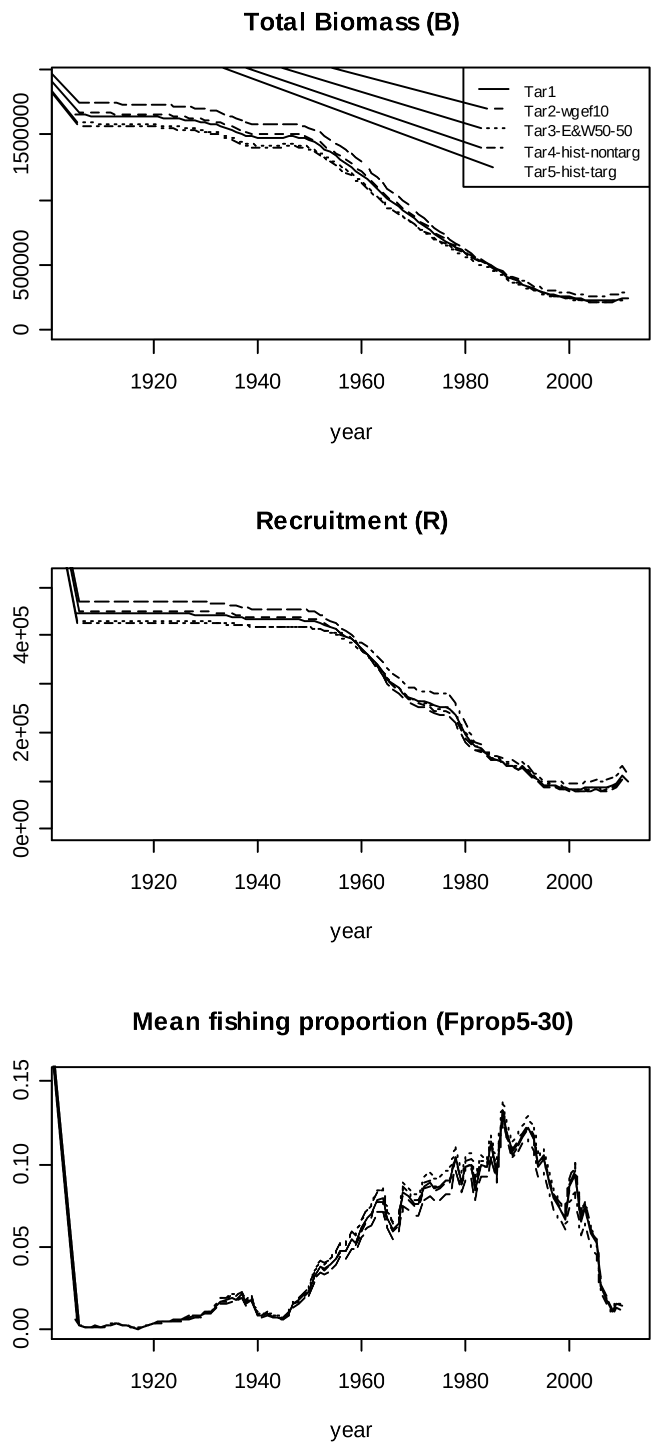


Figure 2.30. Northeast Atlantic spurdog. A comparison of the alternative targeting scenarios, where fishing is defined as either "non-target" (Scottish selectivity) or "target" (England & Wales selectivity). Tar 1 is the base case (each nation is defined "non-target", "target" or a mixture of these, with pre-1980s allocated the average for 1980–1984), Tar 2 is as for WGEF in 2010 (Scottish landings are "non-target", E&W "target", and the remainder raised in proportion to the Scottish/E&W landings, with pre-1980s allocated the average for 1980–1984), Tar 3 as for Tar 2 but with E&W split 50% "non-target" and 50% "target", and Tar 4 and 5 as for Tar 1, but with pre-1980 selectivity entirely non-target (former) or target (latter). This figure is taken from WGEF (2011; i.e. not updated with subsequent data) to illustrate sensitivity to assumptions about historic selection.

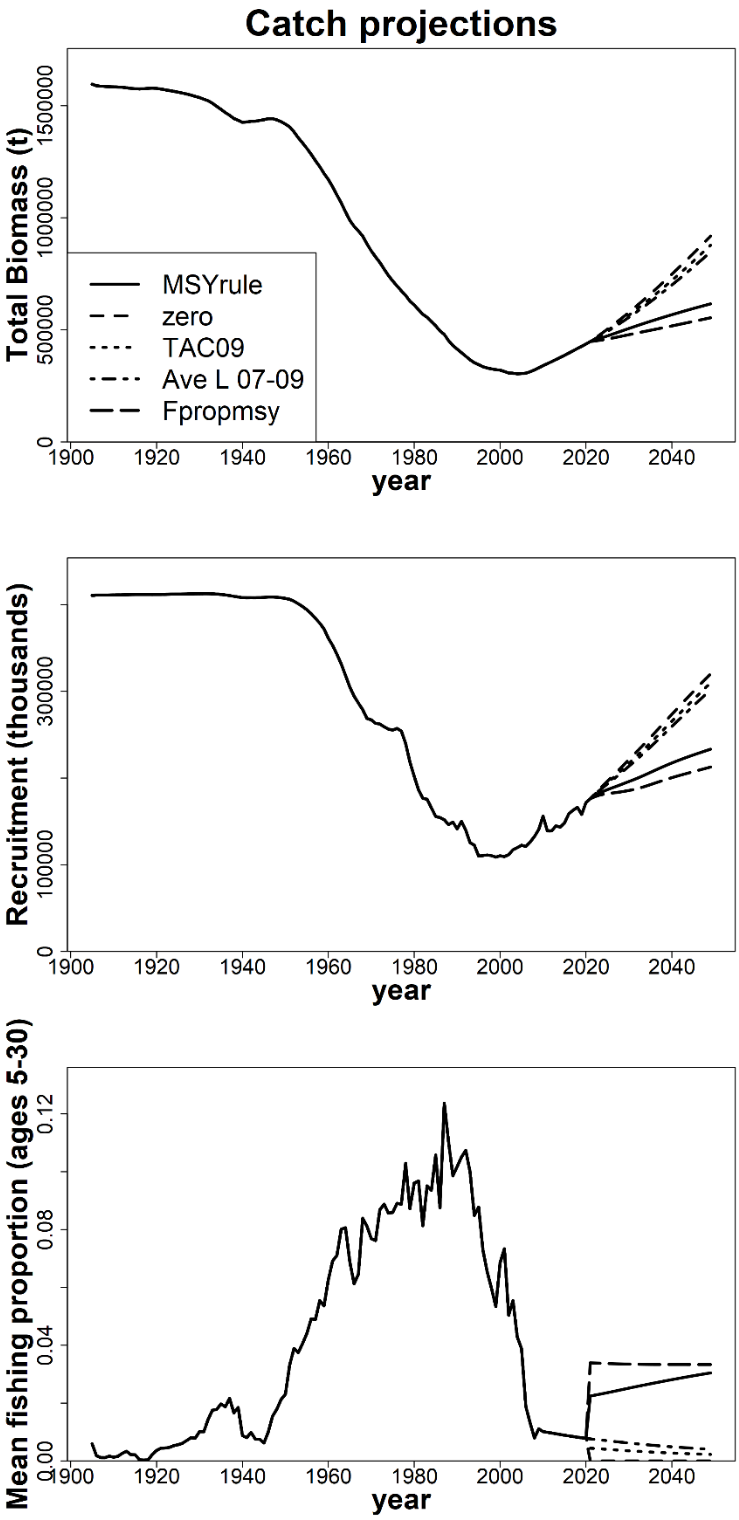


Figure 2.31. Northeast Atlantic spurdog. C_{SQ} assessment. 30-year projections for different levels of future catch, including zero catch for reference.

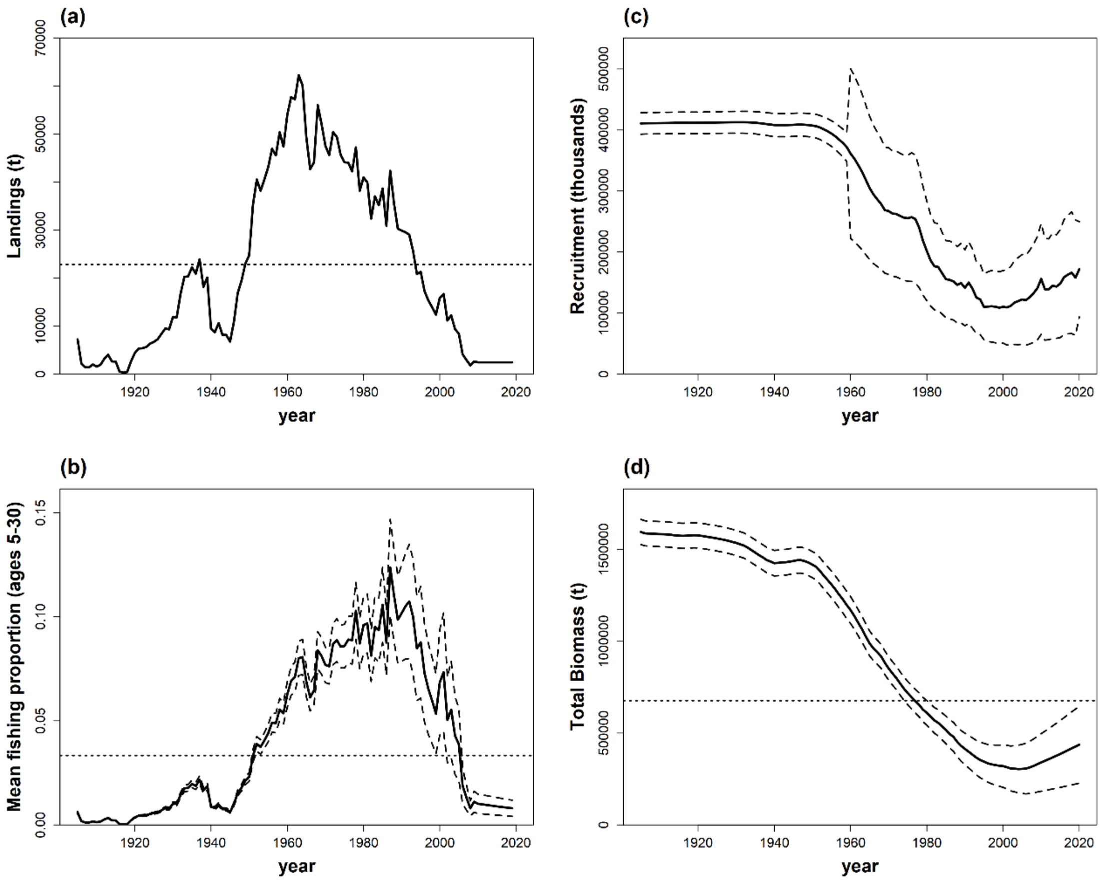


Figure 2.32. Northeast Atlantic spurdog. C_{SQ} assessment. Summary four-plot for the base-case, showing long-term trends in landings (tons; dotted horizontal line = *MSY* = 22 847 t), recruitment (thousands of pups), mean fishing proportion (average ages 5–30; dotted horizontal line = $F_{prop,MSY}$ = 0.033) and total biomass (tons; dotted horizontal line = *MSY* $B_{trigger}$ = 677 068 t). Hashed lines reflect estimates of precision (±2 standard deviations).

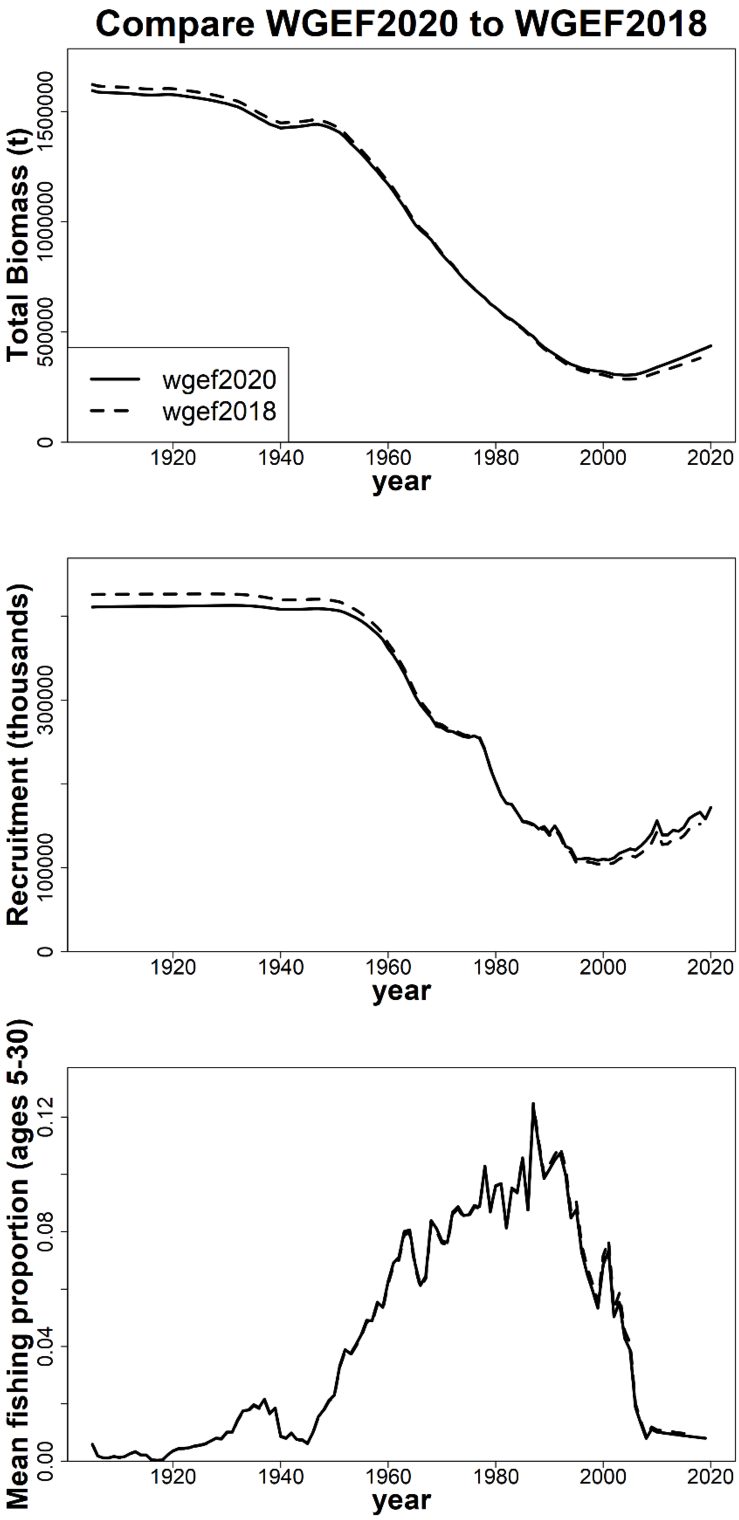


Figure 2.33. Northeast Atlantic spurdog. C_{SQ} assessment. Comparison with the assessment from WGEF (2018).

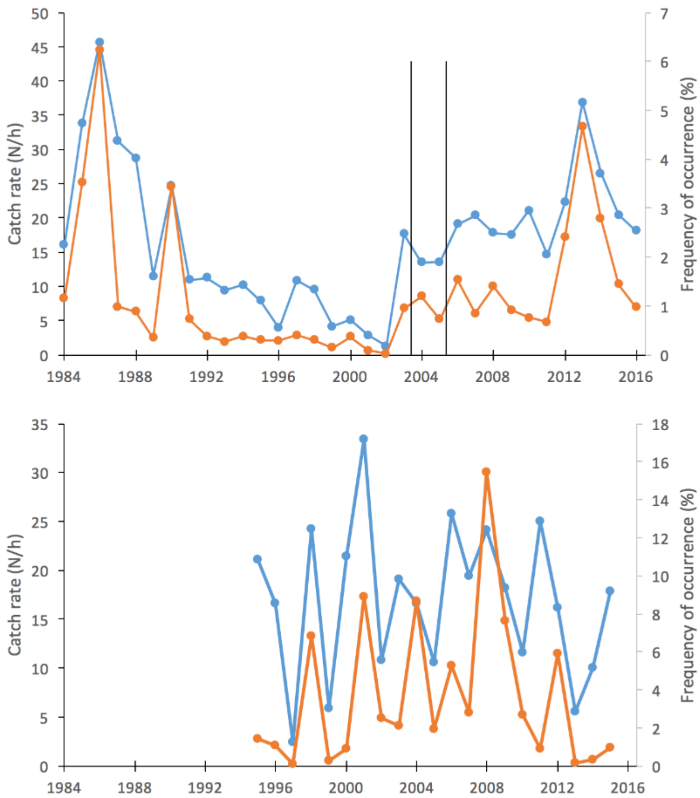


Figure 2.34. Northeast Atlantic spurdog. Survey indices of spurdog in terms of catch rates (orange lines) and frequency of occurrence (blue lines) from the Norwegian Shrimp Survey in South-Norway (top panel) and the Norwegian Coastal Survey in North-Norway (bottom panel). The two vertical lines indicate changes in seasonal coverage of the shrimp survey, being in fourth quarter from 1984, in second quarter from 2004, and in first quarter from 2006.

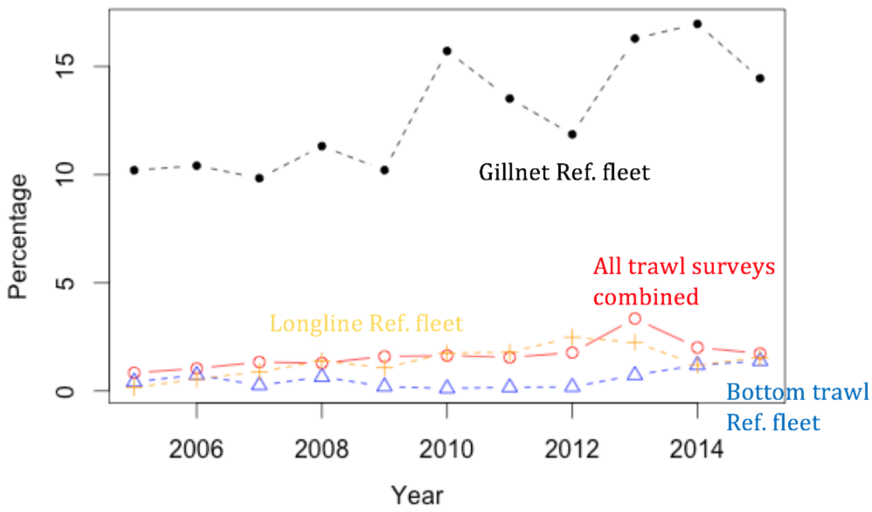


Figure 2.35. Northeast Atlantic spurdog. Percentage occurrence of spurdog in sampled Norwegian commercial catches from each year and from each major fishery groups.

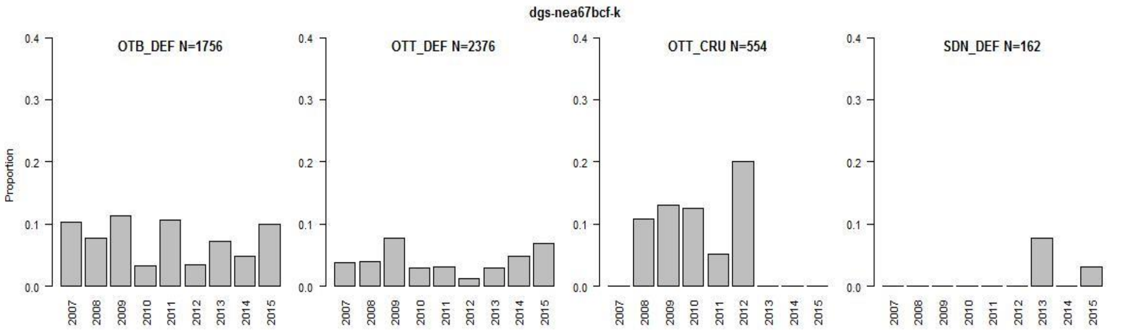


Figure 2.36. Northeast Atlantic spurdog. Proportion of commercial hauls encountering spurdog in French fisheries (main level 5 métiers catching spurdog) in Subarea 6 and divisions 7.b–c and 7.f–k for the period 2007–2015. N: total number of fishing operations sampled for the métier.

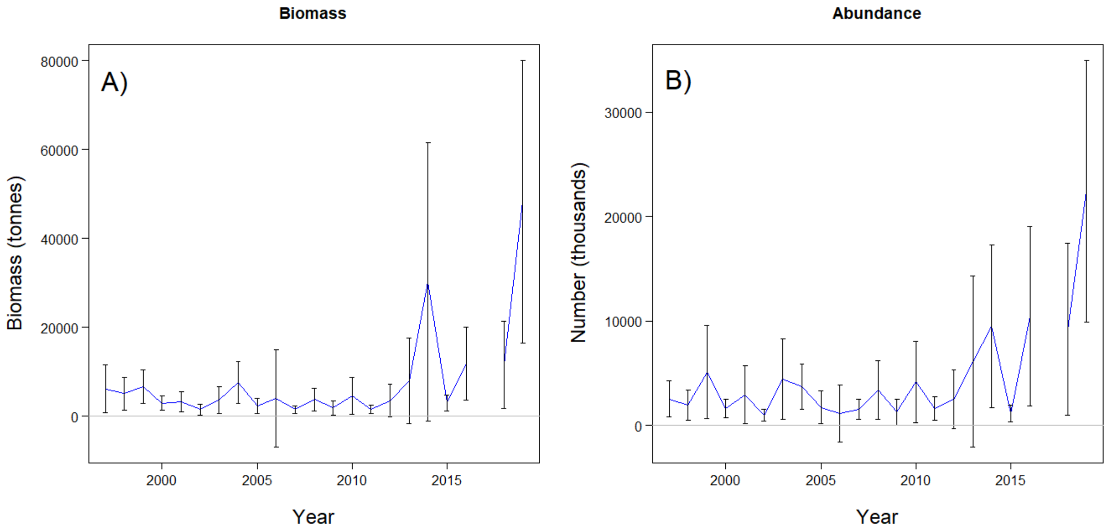


Figure 2.37. Swept area biomass and abundance index of spurdog in the EVHOE (EVHOE-WIBTS-Q4) survey.